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There is more to eye contact than meets the eye

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ABSTRACT

Recent studies have shown enhanced brain and autonomic responses to seeing a face with a direct gaze. Interestingly, greater responses to eye contact vs. averted gaze have been observed when showing "live" faces as stimuli but not when showing pictures of faces on a computer screen. In this study, we provide unequivocal evidence that the differential responses observed in the "live" condition are dependent on the observer's mental attributions. Results from two experiments showed that eye contact resulted in greater autonomic and brain responses compared to averted gaze if a participant believed that the stimulus person sitting on the other side of an electronic shutter was able to see him or her through the shutter. Gaze direction had no effects if participants believed that the transparency from their side was blocked. The results suggest that mental attributions exert a powerful modulation on the processing of socially relevant sensory information.

1. Introduction

Eye contact with another person can have a strong impact on us. Mutual gazing, in addition to mutual touching, has been suggested to be the only mode of actual encounter between two people in a sense that it is only in these activities that "each person both gives and receives in the same act" (Heron, 1970). Encountering a face with a direct gaze not only elicits affective reactions (autonomic arousal) in the observer (Helminen, Kaasinen, & Hietanen, 2011; Nichols & Champness, 1971) but orients attention, facilitates perception, discrimination and memory of facial information (for a review, see Senju & Johnson, 2009), and modulates even cognitive and affective processing of other information concurrently presented in the vicinity (Conty, Gimmig, Belletier, George, & Huguet, 2010; Strick, Holland, & van Knippenberg, 2008).

However, seeing a pair of eyes does not always mean that one is taking part in social interaction. In everyday life, we see faces with a direct gaze – for example, in magazines, television and advertisements – without encountering any true interaction with another person. It is obvious that it would not be adaptive to react similarly to an unknown face staring at you on the other side of the table and to a face staring at you in a magazine.

In recent years, researchers working in the field of social cognition and social neuroscience have become aware that studying social cognition in the laboratory by showing images of other people to passive observers barely touches upon the psychological processes activated when another person is actually present. Researchers have started to ask if the functioning of the social brain network and associated psychological and physiological responses are the same when the experimental participants are looking at a picture or encountering a real person. Furthermore, if differences do exist, what kind of psychological and neural top-down influences are responsible for this modulation (Hietanen, Leppänen, Peltola, Linna-aho, & Ruuhiala, 2008; Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012; Schilbach et al., 2013; Teufel, Fletcher, & Davis, 2010)?

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In a series of studies from our laboratory, we have reported differences in physiological as well as subjective evaluative responses to seeing a picture of a person on a computer monitor vs. seeing a person "live" through a liquid crystal (LC) shutter. In a "live condition", a direct gaze from another person was shown to elicit larger skin conductance responses (Hietanen et al., 2008; Pönkänen, Peltola, & Hietanen, 2011), larger evoked visual brain responses (Pönkänen, Alhoniemi, Leppänen, & Hietanen, 2011; Pönkänen et al., 2008), and more pronounced left-sided frontal electroencephalographic (EEG) alpha-asymmetry (Hietanen et al., 2008; Pönkänen, Peltola, et al., 2011) associated with approach motivation compared to a person's averted gaze or an inanimate dummy's direct gaze, whereas no effect of gaze direction (Hietanen et al., 2008; Pönkänen, Alhoniemi, et al., 2011; Pönkänen, Peltola, et al., 2011) or nature of the model (i.e., a real person vs. a dummy) (Pönkänen et al., 2008) was observed when looking at these stimuli in a pictorial format. Correspondingly, the subjective evaluations showed more self-assessed arousal (Hietanen et al., 2008) and higher public self-awareness (Pönkänen, Peltola, et al., 2011) for a direct gaze compared to an averted gaze in a "live condition" but not when seeing a picture on a computer monitor. It was suggested that the direct gaze results in these effects only when the observer knows that he/she is being looked at by another "mind". This kind of mentalizing does not occur when facing an image or a non-living stimulus, at least not to the same degree as when facing another "live" person.

Other researchers have shown that visual attention orienting by gaze direction cues is modulated depending on the inferences stemming from the stimulus (e.g. are the observed agent's eyes closed or open) (Nuku & Bekkering, 2008), by the belief of whether the observed person can or cannot see (Teufel, Alexis, Clayton, & Davis, 2010), and by the belief of whether the observed agent is intentional or not (Wiese, Wykowska, Zwickel, & Müller, 2012). Also, sensory visual adaptation to gaze direction stimuli has been shown to be modulated by the mental-state attributions of the observer (Teufel et al., 2009). It has become apparent that social perception is not only about perception of the agent but also about making inferences of the mind of the agent.

In this study we continued to ask the fundamental question of why eye contact with another person has an influence on one's affect and cognition. The studies cited above provide convincing evidence that the mere visual input from a pair of eyes directed to the observer is not enough to explain the phenomenon. In our previous studies, we have suggested that a critical factor is whether the observer has an experience of being seen by another person, being a target of another person's attention (Hietanen et al., 2008; Pönkänen, Alhoniemi, et al., 2011; Pönkänen, Peltola, et al., 2011; Pönkänen et al., 2008).

In the present study, we aimed to isolate the influence of this particular factor while keeping our stimulus presentation condition as natural as possible. To this end, we showed the participants a face of a live model with direct and averted gaze through a liquid crystal (LC) window. In one condition, the participant and the model saw each other through the LC window as usual, whereas in another condition, the participant was led to believe that a half-silvered mirror was placed against the LC window in such a way that the model could not see the participant. In reality no half-silvered mirror was used. In the first experiment we thus investigated whether the participant's belief of whether the model could or could not see him/her influenced the effects elicited by eye contact. In the second experiment we went further and asked how much the "eye contact effect" is, in fact, dependent on seeing the other person's eyes? We manipulated not only the participant's belief of the model's ability to see but also the visibility of the model's eyes by using different types of sunglasses.

2. Experiment 1

To investigate whether autonomic reactivity to eye contact is modulated by the observer's mental state regarding whether he or she (i.e., the self) is being observed by another individual, we measured skin conductance responses (SCR) indexing sympathetic affective arousal (Dawson, Schell, & Filion, 2000), and the heart rate (HR) deceleration response as an index of attention orienting to external stimuli (Graham & Clifton, 1966). Previous experiments have shown that seeing another individual's direct gaze results in larger SCRs compared with seeing an averted gaze (Hietanen et al., 2008; Helminen et al., 2011; Nichols & Champness, 1971; Pönkänen, Peltola, et al., 2011). Faces displaying a direct gaze have also been shown to capture and hold visual attention (Conty, Tijus, Hugueville, Coelho, & George, 2006; Senju & Hasegawa, 2005; von Grünau & Anston, 1995), and there is previous evidence showing that the HR deceleration response, known to be amplified by affectively and motivationally salient stimuli (Bradley, 2009; Lang & Bradley, 2010), is greater in a direct gaze when compared with an averted gaze (Akechi et al., 2013).

In addition to autonomic measures, we also measured various electroencephalographic event-related potentials (ERPs) in order to investigate the time-window in which face and gaze processing becomes affected by top-down processes related to the experience of being seen or not seen. The N170 response and the early centro-parietal and lateral occipito-temporal responses are relatively early components shown to reflect both face and gaze-direction processing (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Conty, N'Diaye, Tijus, & George, 2007; Pönkänen, Alhoniemi, et al., 2011). The mid-latency frontal P3 response is related to attention orientation caused by affectively arousing stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Keil et al., 2002) and Conty, N'Diaye, Tijus, and George (2007) have shown that this response is sensitive to gaze directions.

We expected larger SCRs, more pronounced HR deceleration responses, and a larger ERP response to a direct vs. an averted gaze in the condition where the participants believed they were seen by the model. Conversely, we expected the differences in responses to direct vs. averted gaze directions to be reduced or even lacking when the participants believed that the model was not able to see him/her. To supplement the physiological data, we also measured self-assessed social awareness and social presence using the Situational Self-Awareness Scale (SASS) (Govern & Marsch, 2001) and Social Presence Form (SPF) (Short, Willams, & Christie, 1976). Govern and Marsch (2001) have suggested that situational self-awareness consists of three factors: private self-awareness, public self-awareness and awareness of surroundings. Public self-awareness refers to the tendency to attend to aspects of the self that are matters of public display (e.g., overt behavior, mannerisms, expressions), whereas private self-awareness is connected to the tendency to think about more internal aspects of the self (e.g., beliefs, values, feelings). The third factor, awareness of surroundings, refers to the tendency to attend to one's environment (Buss, 1980; Govern & Marsch, 2001). Public self-awareness is also associated with the feeling of being evaluated by another person (Buss, 1980), a feeling which naturally occurs when being looked at by another person. Indeed, previous studies have shown that public self-awareness is greater when being looked at by another (real) person when compared with not looked at Hietanen et al. (2008) and Pönkänen, Peltola, et al. (2011). Heeter (1992) has defined social presence as the sense of "being with others", and Sproull and Kiesler (1986) have suggested that differences in perceived social presence are linked to the amount of social context clues, thus making social presence plausibly connected to being seen – or not being seen – by another person. In line with the physiological measures, we expected the public self-awareness and social presence scores to be higher in the two-way visibility condition when compared with the one-way visibility condition.

2.1. Method

2.1.1. Participants

The participants were 26 right-handed undergraduate students (14 females, 12 males) with normal or corrected-to-normal vision. Five participants (3 females, 2 males) were excluded from the analysis due to not believing in the half-silvered mirror deceit or because they admitted, after the half-silvered mirror condition, that they had forgotten that the model person could not see them. Additionally one female and one male participant were excluded from the ERP analysis and one male from the electrocardiogram (ECG) analysis due to technical error. Hence the final data sample consisted of 21 participants (11 females, 10 males) for the SCR and questionnaire data, 19 participants (10 females, 9 males) for the ERP data and 20 participants (11 females, 9 males) for the ECG data. The ethical statement for the study was obtained from the Tampere Area Ethical Review Board.

2.1.2. Stimuli

A female experimenter acted as a stimulus person. The model person bore a neutral expression and had her gaze either straight ahead or averted 30° to the left or right. The model's face was presented through a voltage-sensitive LC shutter (NSG UMU Products Co., Ltd.). The LC shutter was attached to a black panel positioned between the model and the participant. The size of the shutter window was 30×40 cm. The participant was seated 60 cm from the shutter and the overall distance to the model sitting on the other side was 120 cm.

2.1.3. Experimental procedure

The experiment was conducted in two separate blocks: one for the condition where the participants knew that the model was able to see him/her through the transparent shutter (Belief of being Watched, BW-condition) and another where they believed that the vision of the model was blocked (Belief of not being Watched, BnW-condition). The participants' view (in the sense of retinal image) was identical in the two conditions. Participants were instructed that their task was simply to watch the face of the experimenter while the shutter was open. The deceit was carried out by introducing the participants to a half-silvered mirror type of sheet that was attached to the LC window. A transparent sheet with a thin black frame was slid between the participant and the model so that the participant saw an extra sheet being inserted on the LC window (see Fig. 1, left panel). The participant was then taken to the other side of the shutter. During the walk around the short partition, the model person quickly placed another sheet with an opaque, aluminum-colored surface in front of the LC window (Fig. 1, middle panel). The participant then saw this sheet from the model's side and it was confirmed that it was impossible to see through it (Fig. 1, right panel). When the participant returned to his/her own side of the table, the opaque sheet was cautiously and quickly removed. The presentation order of the conditions (BW-condition/BnW-condition) was counterbalanced across the participants. To control for the suspicion of deceit, the participants were asked after the experiment about their experienced differences between the stimulus presentation conditions. During final debriefing, the deceit was unveiled and the participants were asked directly if they had any doubts about the stimulus person seeing them during the BnW-condition block. The participant was excluded from the analysis if he/she expressed clear doubts of deceit on any of these occasions.

Within each block, two series of measurements were conducted. The first series was intended for the measurements of the SCR and HR responses and it consisted of 16 trials. On eight trials the gaze was direct and on the remaining eight it was averted to the left (four trials) or right (four trials). The presentation order of the stimuli was pseudo-random (no more than two consecutive trials of the same type). The stimulus duration was 5 s with an inter-stimulus interval (ISI) varying between 20 and 45 s. A new trial was allowed after recovery from the previous SCR.

The second series of measurements was to calculate the ERPs and consisted of 160 trials. Of the trials, 80 were with direct gaze and 80 with averted gaze (left or right). The duration of the stimulus presentation was 0.5 s with a 1.5-s ISI. The stimuli were presented in 10-trial sequences repeating the same gaze direction. After each sequence, there was a 15-s break. The order of the 16 sequences was pseudo-randomized so that no more than two consecutive sequences of the same type were allowed.

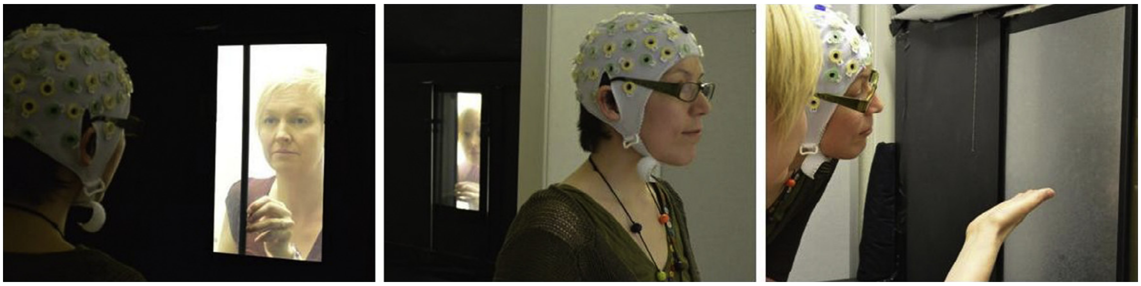

Fig. 1. Illustration of the experimental set-up and the deception procedure. The model slid "half-silvered mirror" (actually a transparent sheet) between a participant and the model (left panel). When the participant was walking to the model's side, the model added quickly another, opaque, sheet in front of the LC-window (middle panel). The participant was convinced that the vision was blocked from the model's side by the "half-silvered mirror" (right panel).

After each block, participants completed two self-assessment questionnaires. The participants were shown a face with a direct gaze (assessments for averted gaze conditions were not collected) for 5 s and then asked to fill in a nine-item SSAS (Govern & Marsch, 2001) and an SPF (Short et al., 1976). SSAS measures three different forms of self-awareness: 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 about my inner feelings) and awareness of the immediate surroundings (e.g., Right now, I am keenly aware of everything in my environment). The SPF was accompanied with an extra item: "I felt very much socially present – I didn't feel socially present at all". Both forms used 7-point scales. Participants were instructed to answer both questionnaires based on their feelings during the previous experimental block, not how they felt in general or at that point in their lives.

2.1.4. Acquisition of the physiological data

For the skin conductance measurements, two electrodes (Ag/AgCl) were attached to the palmar surface of the medial phalanxes of the index and middle fingers of the participant's left hand. For the HR measures, two electrodes (Ag/AgCl) were placed on both arms. The sampling rate for the digitized signals was 1000 Hz.

Continuous EEG was recorded from 64 sites using actiCAP active electrodes, and the signal was amplified with a quickAmp amplifier (Brain products GmbH, Munich, Germany). An average reference was used. The sampling rate for the digitized signal was set to 1000 Hz. Additionally, vertical (VEOG) eye movements were recorded above and below the left eye. Skin abrasion and electrode paste were used to reduce electrode impedances below 25 kOhm.

2.1.5. Data analysis

The SCR data were re-sampled offline to 100 Hz and filtered with a 10 Hz low-pass filter. No high-pass filtering was used. The skin conductance response was defined as a maximum amplitude change from the baseline level (at the stimulus onset) during a 4-s time period starting 1 s after the stimulus onset. In case there was more than a 0.1 μS amplitude rise during the first second after stimulus onset, the trial was rejected. Of all trials, 7.7% was eliminated due to this criterion or because of a technical error. The data were averaged for each condition and gaze direction for each participant, including those with maximum amplitude below 0.01 μMho (i.e. zero responses); this calculation results in the *magnitude* of the skin conductance responses; a measure that combines response size and response frequency (cf., Dawson et al., 2000).

The ECG data were analyzed offline with an in-house (Matlab-based) algorithm to measure the time intervals between two successive R-waves (inter-beat interval, IBI). Trials with excessive distortion in the signal were excluded from the analysis (1.9% of the trials). For a period between 5 s pre-stimulus and 10 s post-stimulus within each trial, the IBIs were quantified and assigned to 1-s intervals. Lastly, IBIs were converted to beats per minute (bpm) and averaged across trials within each condition. A baseline was defined as the average of the IBIs during the 5-s pre-stimulus period. The analyses were performed with HR-change scores that were calculated by subtracting the bpm of each post-stimulus 1-s interval from the baseline.

The continuous EEG signal was offline-filtered with 0.5–30 band-pass filter with 24 dB/oct slope on both ends. The filtered signal was ocular-corrected using a Gratton/Coles algorithm and manually checked for artifacts. In order to study the ERP responses, the signal was segmented into 600-ms long epochs starting 100 ms before the stimulus onset and computed for each condition and gaze direction. The baseline was computed from the 100-ms pre-stimulus period.

In order to study the ERP responses, the signal was segmented into 600-ms long epochs starting 100 ms before the stimulus onset and computed for each condition and gaze direction. The baseline was computed from the 100-ms pre-stimulus period. We analyzed the early N170 response and early centro-parietal and lateral occipito-temporal activity (Conty, N'Diaye, Tijus, & George, 2007; Pönkänen, Alhoniemi, et al., 2011), and the mid-latency frontal P3 response (Cuthbert et al., 2000; Keil et al., 2002).

For the N170 analysis, we pooled the data over three electrodes located in the occipito-temporal region of the right and left hemispheres. These electrodes were PO8/7, P8/7 and P6/5. The minimum amplitude peaks were then identified within a time window of 110–180 ms for each participant in each condition.

Secondly, we analyzed the centro-parietal and left and right lateral occipito-temporal activity during and shortly after the N170 response. Visual inspection showed very similar activity in the centro-parietal electrodes and we decided to pool data over six electrodes (C1, CP1, Cz, CPz, C2 and CP2). On left and right lateral occipito-temporal areas, we pooled the data over electrodes (TP9, TP7 and P7) and (TP10, TP8 and P8). For all three scalp regions, we measured the mean amplitude between 160 and 300 ms separately for each participant in each condition.

Third, we analyzed the frontal P3 component. We analyzed right and left anterior frontal and frontal pole regions averaged over electrodes (AF3, AF7 and Fp1) and (AF4, AF8 and Fp2) and measured the mean amplitude between 200 and 450 ms post-stimulus for each participant in each condition. In addition to the frontal P3, we checked the P3 responses from the central and parietal areas (at and around channels Cz and Pz). However, visual inspection did not show any signs of effects for gaze direction or state of belief and we did not perform any further analyses.

All statistical analyses were conducted using repeated measures ANOVA. Planned comparisons were performed for the analysis of simple main effects when interactions were observed. A Greenhouse–Geisser correction procedure was applied when appropriate. SCR and HR data were not normally distributed and were normalized using ln-transformation. In Section 3, Figs. 2 and 3 show the statistics based on the untransformed values. All analyses were done to normally distributed variables.

2.2. Results

Fig. 2 shows the mean SCR values for each gaze direction in the BW and BnW-conditions. The SCR were subjected to an analysis of variance (ANOVA) with state of belief (BW-condition, BnW-condition) and model's gaze direction (direct, averted) as within-subjects factors. The ANOVA indicated significant main effects for gaze ($F_{(1,20)} = 5.4$, $p = .03$, $\eta^2_p = 0.21$) and for state of belief ($F_{(1,20)} = 4.9$, $p = .04$, $\eta^2_p = 0.20$). Importantly the interaction between the main effects was significant ($F_{(1,20)} = 5.8$, $p = .03$, $\eta^2_p = 0.23$). Pairwise comparisons indicated that the SCR was greater for direct gaze compared to averted gaze in the BW-condition ($t = 3.2$, $df = 20$, $p < .01$, $d = 0.70$) but not in the BnW-condition ($t = .40$, $df = 20$, $p = .70$, $d = 0.09$).

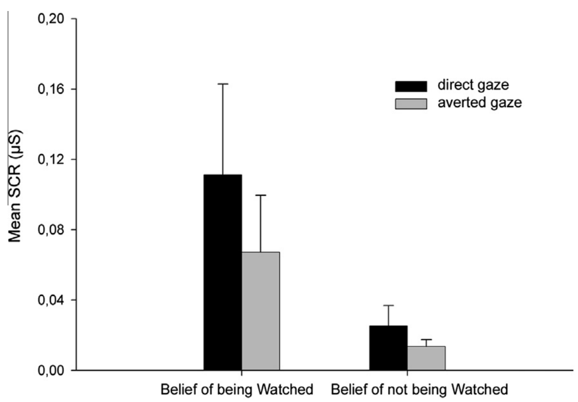

Fig. 2. Skin conductance responses (mean + s.e.m.) to direct and averted gaze in two presentation conditions. In the BW-condition, the model and the participant both saw each other. In the BnW-condition, the participant believed that a half-silvered mirror prevented the model from seeing him/her.

The HR-change scores are presented in Fig. 3. The results showed an HR deceleration response in all conditions. The HR scores were subjected to a 2 × 2 × 10 ANOVA, with state of belief, gaze direction and the time interval after the stimulus onset (0–1 s, 1–2 s,. . .,9–10 s) as within-subjects factors. The ANOVA revealed a main effect for gaze ($F_{(1,19)} = 4.7$, $p = .04$, $\eta^2_p = 0.20$) and time ($F_{(9,19)} = 36.4$, $p < .001$, $\eta^2_p = 0.91$) as well as an interaction between state of belief and gaze ($F_{(1,19)} = 19.3$, $p < .001$, $\eta^2_p = 0.50$). When analyzing the state of belief conditions separately (data averaged across time-points), *t*-tests indicated that the HR deceleration was more prominent for direct than averted gaze ($t = 3.5$, $df = 19$, $p = .002$, $d = 0.79$) in the BW-condition, whereas the difference was not significant ($t = 0.1$, $df = 19$, $p = .91$, $d = 0.03$) in the BnW-condition.

For cortical ERP-responses, we first analyzed the face-sensitive N170 responses recorded from the occipito-temporal regions. The stimuli elicited clear N170 responses in all conditions. However, an ANOVA revealed no main effects (state of belief, gaze direction and hemisphere) or interactions (all *ps* > .1).

The mean amplitude between 160 and 300 ms post-stimulus was analyzed over the centro-parietal electrodes and the right and left lateral occipito-temporal electrodes. A 2 × 2 × 3 ANOVA having state of belief, gaze direction and scalp region (right, central, left) as within-subjects factors showed an interaction between gaze direction and scalp region ($F_{(2,36)} = 18.9$, $p < .001$, $\eta^2_p = 0.44$). Further analyses showed that direct gaze induced a more negative response compared to averted gaze over the centro-parietal region ($t = -2.8$, $df = 18$, $p = .012$, $d = 0.62$), whereas this polarity difference was reversed over the right occipito-temporal site ($t = 6.4$, $df = 18$, $p < .001$, $d = 1.31$). Gaze direction had no effect on the responses measured over the left occipito-temporal region ($t = 0.4$, $df = 18$, $p = .723$, $d = 0.03$). State of belief or any other conditions were not significant. The grand-averaged ERPs are illustrated in Fig. 4.

For the frontal P3 component (mean amplitude between 200 and 450 ms post-stimulus), a 2 × 2 × 2 ANOVA (state of belief × gaze direction × hemisphere) revealed the main effects of gaze direction ($F_{(1,18)} = 8.7$, $p < .01$, $\eta^2_p = 0.33$) and hemisphere ($F_{(1,18)} = 37.0$, $p < .001$, $\eta^2_p = 0.67$). Importantly there was an interaction between gaze direction and state of belief ($F_{(1,18)} = 5.6$, $p = .03$, $\eta^2_p = 0.24$). Pairwise comparisons showed that in the BW-condition, the P3 response (averaged across hemispheres) was significantly shifted in the positive direction to direct vs. averted gaze ($t = 3.5$, $df = 18$, $p < .01$, $d = 0.80$), whereas in the BnW-condition, such an effect was not present ($t = 1.1$, $df = 18$, $p = .31$, $d = 0.24$). The grand averaged P3 ERPs are presented in Fig. 5.

For self-assessment ratings, a *t*-test indicated stronger public self-awareness in the BW-condition than in the BnW-condition ($t = 2.5$, $df = 20$, $p < .05$, $d = 0.56$). For private self-awareness and awareness of immediate surroundings, no significant differences were found. Self-assessed social presence was stronger in the BW-condition compared to the BnW-condition ($t = 3.1$, $df = 20$, $p < .01$, $d = 0.68$) (Table 1).

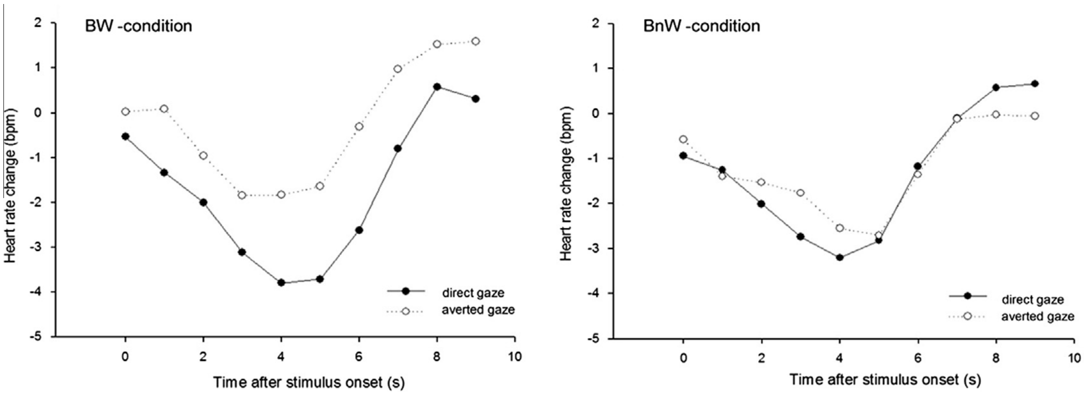

Fig. 3. Heart rate changes in relation to direct and averted gaze in two presentation conditions.

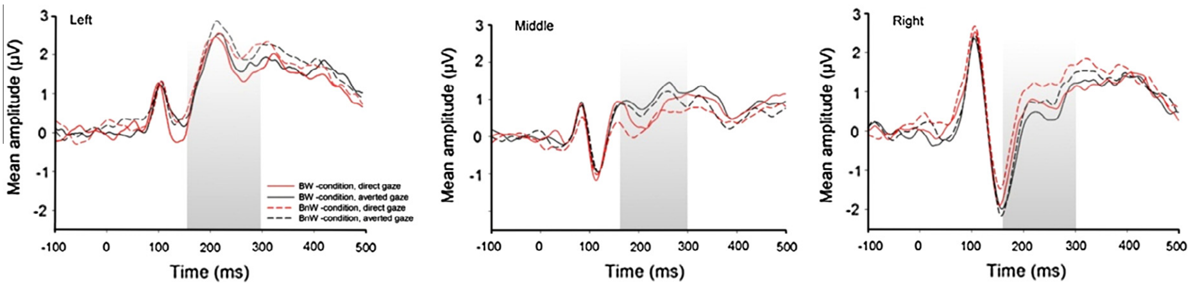

Fig. 4. Grand-averaged ERP waveforms to direct and averted gaze in two presentation conditions. Waveforms are separately presented for centro-parietal (middle) and for left and right temporo-parietal electrode sites. The shaded area shows the time frame of interest (160–300 ms).

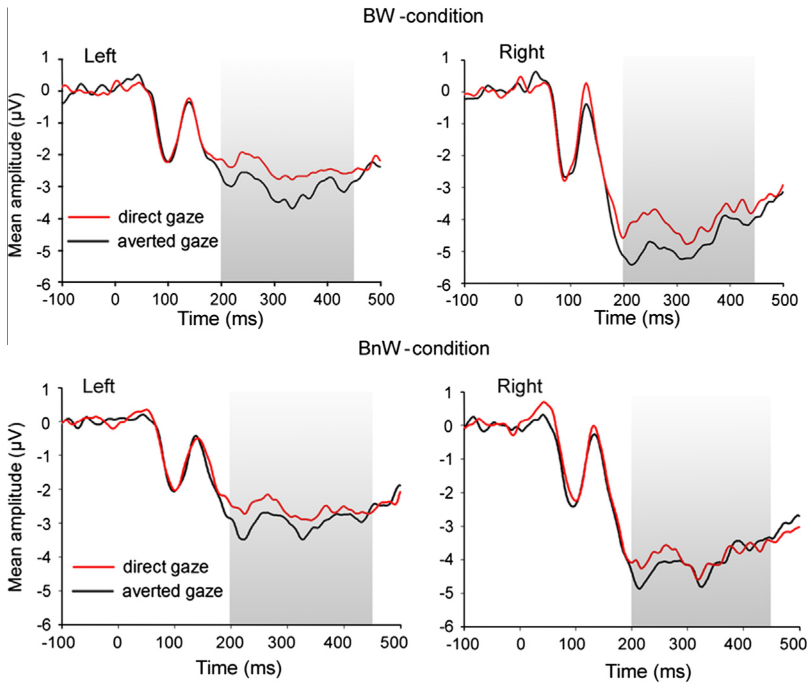

Fig. 5. Grand averaged frontal P3 waveforms to direct and averted gaze in two presentation conditions. Waveforms are separately presented for left and right frontal electrode sites. The shaded area shows the time frame of interest (200–450 ms).

Table 1
Self-rated SSAS (Situational Self-Awareness Scale) and social presence (SPF) scores for two different presentation conditions. The SSAS scores include three factors of self-awareness (public, private, and surroundings). Scale range in all scores is 1–7.

Presentation condition	Public		Private		Surroundings		Social presence	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
BW-condition	2.73	1.47	3.56	1.31	3.33	1.29	4.06	0.94
BnW condition	2.15	1.12	3.67	1.29	3.23	1.19	3.63	0.94

In order to analyse, whether public self-awareness and social presence were influencing the physiological responses, we analyzed the correlations between public self-awareness and SCRs and between social presence and SCRs (separately in the two state of belief conditions and for the two gaze directions). In the BW-condition, the correlations suggested that participants reporting higher levels of public self-awareness had greater SCRs. This applied both to direct and averted gaze. However, the evidence was not strong as the correlations only approached statistical significance ($r_{\mathrm{DirectGaze}} = .356$, $p = .081$) and ($r_{\mathrm{AvertedGaze}} = .347$, $p = .089$). The corresponding correlations in the BnW condition were not significant (*ps* > .2). For social presence, the corresponding analyses showed no connection between social presence and SCRs (all *ps* > .2).

3. Experiment 2

In Experiment 2, we wanted to investigate whether the "eye contact effect" observed in Experiment 1 was dependent on seeing the other person's eyes. Senju and Johnson (2009) defined the eye contact effect as "the phenomenon that perceived eye contact modulates the concurrent and/or immediately following cognitive processing and/or behavioral response", and their fast track modulator model postulates that eye contact effect relies on the processing of visual information from the eyes by subcortical mechanisms, which then modulate the cortical processing. However, as the results of Experiment 1 showed, the enhancement of the autonomic and cortical responses to direct gaze was entirely dependent on the participants' beliefs about being seen, thus the findings prompt one to ask what kind of a role the eyes play as a visual stimulus in the observed results. If the critical factor is an observer's experience of being watched or not, then the visibility of another individual's eyes is perhaps not necessary. In Experiment 2, we manipulated not only the participant's belief in the model's ability to see the participant, but also the visibility of the model's eyes. In three different experimental blocks, a new sample of participants saw a live model with a direct or averted head orientation. In each block, the model wore a different pair of sunglasses: a pair without lenses so the model's eyes were visible; a pair of normal sunglasses with dark lenses; and a pair with blocked lenses so the model could not see through them. The normal and blocked sunglasses looked identical to the participants. The participants were always informed of which sort of glasses the model was wearing. In this experiment, we only measured the affective autonomic responses (SCR). If the autonomic response is dependent on seeing the eyes, we should not expect to observe differences in SCRs between direct and averted head orientation in the two conditions obscuring the visibility of the eyes. However, if the experience of being seen by another person is crucial for the enhanced autonomic responses, we should expect to observe larger responses to a direct vs. averted head orientation regardless of the visibility of the model's eyes, so long as the observer knows that the other person is able to see him or her. We therefore expected to observe the latter pattern of results.

3.1. Method

3.1.1. Participants

The participants were 24 undergraduate students (13 females, 11 males, mean age 27.0 years, range 21–53 years) with normal or corrected-to-normal vision. The ethical statement for the study was obtained from the Tampere Area Ethical Review Board.

3.1.2. Stimuli

The stimulus was the face of an assisting experimenter (male or female). Half of the participants saw a male face and the other half saw a female face. The sex of the participants was balanced with respect to the sex of the model person. The model person had a head orientation either straight ahead or rotated 30° to the left or right. The model always looked in the same direction where his/her head was oriented. In this experiment, the stimuli were presented normally through the LC window. The half-silvered mirror deceit procedure was not used here. Otherwise the stimulus presentation was as in Experiment 1.

3.1.3. Experimental procedure

The experiment included three experimental blocks. In one block, the model wore dark sunglasses, thus obscuring his or her eyes. In the second block, the model wore similar sunglasses, but the insides of the lenses were covered so that it was impossible to see through them. The external view of the sunglasses in these two blocks looked exactly the same. In the third block, the model wore a similar pair of sunglasses but with the lenses removed, thus allowing the eyes to be seen. Before the experiment, the participants were allowed to examine the different sunglasses/frames to convince them that it was possible to see through the normal sunglasses while it was impossible to see through the covered ones. The presentation order of the blocks was counterbalanced across the participants.

There were 12 trials within each block. For six trials, the model's head was oriented directly toward the participant and for the remaining six trials it was rotated to the left or right. Within a block, the presentation order of stimuli was pseudo-random (no more than two consecutive trials of

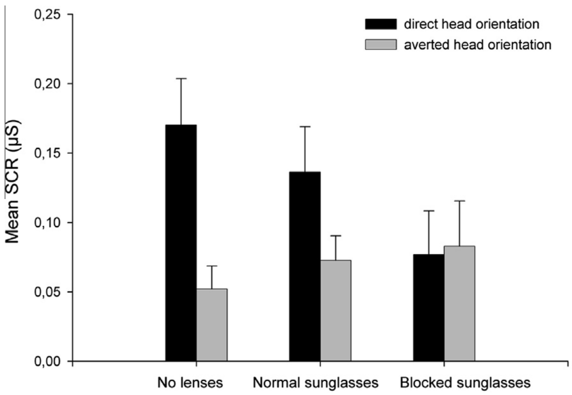

Fig. 6. Skin conductance responses (mean + s.e.m.) to direct and averted gaze in three presentation conditions (Experiment 2). In the "no lenses" condition, participants saw a model wearing sunglasses frames without lenses (eyes visible). In the "normal lenses" condition, a model was wearing normal sunglasses (eyes not visible, but the model saw through the lenses). In the "blocked lenses" condition, a model was wearing sunglasses with the lenses blocked from the inside (eyes not visible, the model could not see through the lenses).

the same type). The stimulus duration was 3 s with an ISI varying between 20 and 45 s. A new trial was allowed after recovery from the previous SCR.

3.1.4. Acquisition of the physiological data and data analysis

The SCR data were acquired and analyzed in a similar manner as for Experiment 1. From all the trials, 11.2% was eliminated due to responding too early or a technical error.

3.2. Results

The SCRs were analyzed using a 2 × 3 within-subjects ANOVA. The ANOVA indicated a main effect of head orientation ($F_{(1,23)} = 9.0$, $p < .01$, $\eta^2_p = 0.29$) and an interaction between head orientation and sunglass condition ($F_{(2,46)} = 4.1$, $p = .033$, $\eta^2_p = 0.16$). When analyzing the three sunglass conditions separately, *t*-tests indicated larger SCRs to direct vs. averted head orientation when the glasses had no lenses ($t = 3.4$, $df = 23$, $p < .01$, $d = 0.68$) and when the lenses were normal ($t = 3.2$, $df = 23$, $p < .01$, $d = 0.67$) but not when the lenses were blocked ($t = 0.4$, $df = 23$, $p = .72$, $d = 0.07$). The SCRs to direct head orientation were not significantly larger when the eyes were visible (no lenses) compared with when they were covered by normal sunglasses ($t = 0.7$, $df = 23$, $p = .50$, $d = 0.14$). However, the SCRs to direct head orientation in both of these conditions were larger than the SCRs to direct head orientation when the model wore blocked lenses (both *p*s < .02). The mean SCR values in all three conditions are shown in Fig. 6.

4. Discussion

The results unveiled an intriguing interplay between gaze direction and mental attributions affecting physiological and self-assessed responses. Autonomic SCRs and HR deceleration responses were larger and the cortical P3 response was more positive for direct gaze than for averted gaze, but only when the participants believed that the model could see him/her. To complete the consistent pattern of physiological results, the subjective ratings showed higher levels of public self-awareness and social presence when the model was able to see the participant compared with when the model was not. Based on the results of our earlier studies demonstrating differences in physiological and self-assessed measures in response to seeing a real person and seeing a picture (Hietanen et al., 2008; Pönkänen, Alhoniemi, et al., 2011; Pönkänen, Peltola, et al., 2011; Pönkänen et al., 2008), we have hypothesized that the critical factor may be the observer's knowledge of being the target of another individual's attention or not. The present findings provide strong support for this hypothesis and provide further evidence that top-down influences have a major role in governing the reactions to another person's eye gaze.

We argue that the presence of another individual who has the potential to see and attend to an observer initiated mentalizing in the observer. In this situation, if the observer detected that the other individual's attention was directed to himself/herself, the observer was prone to viewing himself/herself in the second person perspective. The "self" was experienced as the object of another's attention (cf., Reddy, 2003). Specifically, in our study, this heightened the observer's public self-awareness (but not private self-awareness or awareness of surroundings) as well as feelings of social presence. Concomitant with the psychological-level reactions, a "true" eye contact also resulted in enhanced autonomic responses associated with affective arousal (SCR) and attention allocation (HR deceleration) as well as cortical responses (P3) reflecting attention orienting by motivationally salient stimuli. On the other hand, if the observer knew that the other individual was not able to see him/her, the other individual's gaze direction had no effects on the subjective evaluations or physiological responses. Taken together, the present findings provide strong evidence that the observer's knowledge of being the target of another individual's attention or not has a major role in governing the reactions to another person's eye gaze. We also suggest that enhanced self-awareness due to mutual eye contact may play a central role in the observed eye contact effect.

We were also able to show that the visibility of the other person's eyes, in fact, may not be necessary at all in order to observe the "eye contact effect". We observed larger SCRs to direct head/gaze vs. averted head/gaze both when the model was wearing sunglasses without lenses and also when wearing sunglasses with normal dark lenses hiding the eyes. Additionally the autonomic response to direct head/gaze was not stronger when the model's eyes were visible compared to when the model wore normal sunglasses. Thus, seeing the other person's eyes seems to play a negligible role in the "eye contact effect". However, cautiousness is required when interpreting this last result: it is possible that the experiment was not sensitive enough to reveal the difference between visible and non-visible direct eyes. The discriminative sensitivity was maximal for conditions presented within a block (i.e., direct vs.

averted gaze) but not for between-block conditions. Future studies must resolve whether the visibility of the eyes contributes further to the strength of the measured responses or not.

Regarding the cortical brain responses, the results replicated earlier results showing that the N170 response suggested to reflect the structural coding of the face (Bentin et al., 1996) was not sensitive to the gaze direction (Pönkänen et al., 2008; Taylor, Itier, Allison, & Edmonds, 2001), although, in some studies, gaze direction effects on N170 have been reported (Conty et al., 2006; Puce, Smith, & Allison, 2000; Pönkänen, Alhoniemi, et al., 2011). However, another early component measured from the centro-parietal and temporal regions during the time interval of 160–300 ms post-stimulus discriminated between the direct and averted gaze. This differential cortical activity between gaze directions was observed regardless of the participant's state of belief. Similar differences between gaze directions on cortical activity at this latency range have previously been reported for typically developed children (Senju, Tojo, Yaguchi, & Hasegawa, 2005) and adults (Conty et al., 2006). It has been suggested that this component may reflect additional face-related processes taking place during N170, but being distinct from it (Conty et al., 2006; Senju et al., 2005). As we observed gaze direction sensitivity on these centro-parietal and temporal cortical channels in the absence of N170 effects, our results build on the evidence for this suggestion.

The frontally measured P3 response considered to reflect attention orienting by affectively arousing stimuli (Cuthbert et al., 2000; Keil et al., 2002) was more positive to direct gaze vs. averted gaze only when the participant knew that the model was able to see him/her. This result combined with the other observed ERP results suggests that the presently investigated top-down influences do not modulate the more posterior ERP responses reflecting lower stages of visual information processing, but exert their influence on higher stages of processing. At first, this may seem contradictory considering, for example, the recent results showing the influences of mental-state attributions on sensory visual adaptation to gaze direction stimuli (Teufel et al., 2009). Experiments combining gaze direction adaptation and functional magnetic resonance imaging (fMRI) have localized these effects to the human superior temporal sulcus (STS) (Calder et al., 2007). However, the studies using fMRI have not revealed the time-course of the gaze direction adaptation effect. Thus, mentalization may exert its effect on the gaze direction processing in the STS, but not on the early stages of processing. Naturally, more research is needed to resolve how strongly and how early top-down influences can affect different types of cortical social information processing.

Neuroimaging evidence suggests that medial prefrontal cortex (mPFC) activation is linked to mentalization processes and feelings of involvement in social interaction (Amodio & Frith, 2006; Schilbach et al., 2006), and it has been proposed that the mPFC plays a prominent role in modulating the processing of visual information in a social context (Schilbach et al., 2013; Teufel, Fletcher, et al., 2010). It is possible that the "state of belief" modulation effects on the observed physiological responses may reflect the effect of the mPFC modulation. A theoretically interesting question is, of course, whether the observed response modulations reflect direct effects by mentalization or whether they are mediated by some other intervening mechanisms. As suggested in our earlier study (cf. Pönkänen, Alhoniemi, et al., 2011), these types of effects could be related to the potential for interaction between the participant and the model. For example, Shimada and Hiraki (2006) have shown that participants' sensory-motor brain activity is enhanced in response to the viewing of human actions vs. viewing object movement when both stimulus types are presented in a live setting, but not when presented on a screen. Thus, it is possible that participants experienced greater interaction potential in the belief of being watched (BW) condition than in the belief of not being watched (BnW) condition. Another possibility is that the observed effects were mediated by so-called audience effects, including concerns about one's reputation in the eyes of another individual (Frith & Frith, 2012). The audience effect in our experimental situation can be interpreted as one example of mentalizing processes; it was also likely to be greater in the BW than in the BnW condition. An additional possibility relates to attentional effects. Looking at another individual's direct gaze is likely to result in greater allocation of attentional resources when one knows that one is being watched oneself vs. when one is not being watched. In any case, it is important to note that whatever the involved mechanisms are, the core factor is likely to be related to whether one is being watched by another individual or not.

As this and several other recent studies show, the human visual information processing does not depend only on the input, the retinal image, but also on the higher-order processes such as the mental attributions taking place in the experimental situation. We want to emphasize that we are not arguing that this type of top-down modulation occurs only when facing a real person who is physically present: several studies show that it can also be observed when participants are looking at another person via video-link or even when looking at inanimate stimuli (Nuku & Bekkering, 2008; Teufel, Alexis, et al., 2010; Teufel et al., 2009; Wiese et al., 2012) but it may be the case that the use of less natural social stimuli does not elicit such robust top-down effects, or does so perhaps only in the minority of participants, as does the use of more natural stimuli. The present results provide strong evidence that these types of processes have a profound impact on the processing of social information.

An interesting topic for future studies will be to investigate more extensively the modulatory effects that top-down influences can have on a variety of processes involved in gaze, face and body perception. It is also imperative to examine e.g. to what degree it is possible to voluntarily control the activation of different types of mentalization processes, what kind of factors are critical in elicitation of this kind of mentalization and whether the consequences of "simulated mentalization" are similarly observed in the context of spontaneously occurring mentalization. This kind of research can potentially have a great impact on our understanding of social perception.

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