# NOW I SEE YOU, NOW I DON'T

**- Responses to eye contact are modulated by the belief of whether being seen or not.**

University of Tampere

School of Social Sciences

and Humanities

Aki Myllyneva

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Brain and autonomic responses elicited when seeing a face with straight gaze differ from those elicited when seeing a face with averted gaze. Recent studies have shown that the differential responses are elicited only when showing live faces as stimuli but not when showing pictures on a computer screen. An interesting question is what is the underlying reason for the differential responses between seeing a live face and seeing a picture. It is possible that it is not the differences in retinal images, but differences in higher order mental processes that have a crucial effect on responses to faces. In this study we concentrate on the influence of being or not being seen on the brain and autonomic responses to faces.

We measured participants' skin conductance responses (SCR), heart rate (HR) and electroencephalogram (EEG) when showing a face of a live model with a direct and averted gaze. These measurements were carried out in two conditions: 1) when the participant knew that the model was able to see him/her and 2) when the participant was led to believe that the model's vision was blocked. The latter condition was accomplished by leading the participant to believe that we used a special one-way mirror –type of sheet allowing the visibility only from one side of the sheet. In both conditions, the view from the participant's side was exactly the same. The results showed that the SCR and HR responses, as well as a frontal P3 –component of event related potentials (ERP) were enhanced to direct gaze, but only when participant believed that he/she was being looked at by the model person. Additionally, early negative parietal and centro-parietal ERP components were enhanced to direct gaze regardless of presentation condition. Frontal EEG asymmetry in the alpha-band activity and N170 amplitude did not show any sensitivity to gaze direction or presentation condition. The results suggest that mental attributions – the belief of being or not being seen by another person – can have a strong impact on autonomic and brain responses.

Keywords: gaze direction, theory of mind, skin conductance, heart rate, electroencephalogram

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# 1. Introduction

A direct gaze of another person can have a strong impact on us. Gaze has been compared to touch as being a powerful reinforcer of communication in social situations (Brockner, 1982). Mutual touching and mutual gazing have even been suggested to be the only modes of actual encounter between two people, in a sense that only in mutual gazing and mutual touching each participant gives and receives in the same act (Heron, 1970). However, seeing a pair of eyes does not always mean that one is experiencing a social encounter. When looking at a face with direct gaze but knowing at the same time that one is not being looked at himself, for example, when looking at a picture of a face, one can hardly be said as experiencing somebody's gaze. Also, when seeing another person's gaze but orienting to the eyes purely as physical objects, for example, when removing a speck of dirt from somebody's eye or when investigating the color or shape of the iris, the situation is again quite different from actually encountering the gaze (Heron, 1970). Thus, it appears that there is much more to perceiving a face and a gaze than just the retinal image. One of the most fascinating questions in social neuroscience is how different situational factors, knowledge, beliefs and mental attributions influence on social perception such as face and gaze processing.

## 1.1. Social aspects of eye gaze

Eye region is the most attended of all facial areas (Itier, Villate, & Ryan, 2007). The morphology of the human eye is extremely well suited for communicating: it possesses the largest ratio of exposed sclera relative to the eye outline of all species (Kobayashi & Kohshima, 1997) thus helping to discriminate gaze direction even at a distance. Face recognition performance drops if the eye region is masked, while masking of the mouth region does not cause similar effects (McKelvie, 1976). Also face detection performance, measured by speed of detection, is more severely impaired by masking the eye region compared to occlusion of the mouth, nose or forehead (Lewis, 2003).

Human face and especially the eyes serve many functions in social situations. By using eye gaze people provide information, regulate interaction, express intimacy, exercise social control and facilitate task goals (Kleinke, 1986). Gaze is especially important in initiating interaction (Argyle, 1988). When communicating, people get constant feedback of their own behavior from others' gaze

(Argyle, 1988). It has been suggested that exchanging gazes in a community serves a function of maintaining social bonds and forming alliances in a similar manner as social grooming does for many primates (Kobayashi & Hashiya, 2011).

Direct gaze usually signals positive feelings, such as liking, closeness and interest. Averted gaze, on the other hand, is often related to submissiveness, appeasement or lack of interest (Kleinke, 1986). For other animals, direct gaze is mostly interpreted as threatening or signaling dominance (Emery, 2000). However, in human encounter, too, direct gaze, when prolonged, is usually experienced as unpleasant and intrusive (Argyle, Lefebvre, & Cook, 1974). There is some evidence of gender differences in direct gaze preferences. In one study, it was found that women liked males and females more with high levels of direct gaze whereas men preferred males or females with lower levels of direct gaze (Kleinke, Bustos, Meeker, & Staneski, 1973). In another experiment, females expressed more intimacy to a same sex listener when the listener provided direct gaze compared to when the listener provided gaze aversion, but for males the result was the opposite (Ellsworth & Ross, 1975).

Not surprisingly, humans are relatively accurate in evaluating if another person's gaze is directed to them or somewhere else (Gamer & Hecht, 2007). This ability seems to be innate: as young as 2-5 days old infants are able to discriminate between direct and averted gaze (Farroni, Csibra, Simon, & Johnson, 2002). However, only after the age of 6 years is the gaze direction evaluation accuracy fully developed, and it has been suggested that weaknesses in sensitivity to direct vs. averted gaze limits small childrens' ability to make social judgments using gaze cues (Vida & Maurer, 2012). In adults, it has been shown that the ability to judge between the existence and absence of mutual gaze is not constant but susceptible to situational and personal factors (Gamer & Hecht, 2007; Gamer, Hecht, Seipp, & Hiller, 2011; Penton-Voak, Cooper, Roberts, Attwood, & Munafò, 2012). For example, patients with social phobia estimated more easily that the gaze was directed at them when it actually was slightly averted (Gamer, Hecht, Seipp, & Hiller, 2011).

Gaze carries a load of information about preferences and attraction. We usually look more at the things we like. People also intuitively know this and make inferences about others' preferences based on their gazing behavior (Kleinke, 1986). For example, people in photographs appear to like each other more when sharing an eye contact (Lim, 1972). Also men and women with high levels of mutual gaze are seen as having more sexual interest compared to having low levels of mutual gaze (Thayer & Schiff, 1977). Other people's gazing behavior has an effect on our own evaluation of people and objects, too. We prefer faces that gaze at us compared to faces that gaze somewhere else

(Mason, Tatkow, & Macrae, 2005) and we like more those objects that are gazed at compared to those towards which no attention is signaled (Bayliss, Paul, Cannon & Tipper, 2006). This effect seems to persist even if the gazer clearly is not very competent in assessing the quality of the object. Namely, it has been shown that consumer products are evaluated more positively when a dog looks towards them compared to a situation where a dog looks at the other way (Corneille, Mauduit, Holland, & Strick, 2009).

## 1.2. Gaze-cueing and attention orienting

The amount of visual information we are receiving is enormous and it is necessary to sort out the most important input for further processing. This is done by attending selectively to relevant aspects of the environment. Orienting of attention can be divided to overt or covert orienting (Posner, Snyder, & Davidson, 1980). Overt orienting refers to changes in attention due to body, head and eye movements, for example moving your eyes toward an object of interest to enable optimal processing. Covert orienting on the other hand may be achieved by the alignment of mental focus of attention towards the target stimulus.

Another way to distinguish between different types of orienting is to examine how attention orientation is controlled. It can be done in an automatic manner, reflexively. This type of orienting is usually referred to as bottom-up or exogenous attention orienting. Attention control can also be voluntary and referred as top-down or endogenous control of attention (Frischen, Bayliss, & Tipper, 2007). These differences are important when investigating where and how attention is oriented and which mechanisms are involved.

In social situations, information about another individual's gaze direction is vitally important. When observing someone gazing in a specific direction we can gain information about the gazer's preferences and make predictions about his or her behavior. Usually when we see someone gazing in a specific direction we turn our own gaze in the same direction. This joint attention is an important mechanism in infant learning, and it can be seen even in neonates (Farroni, Massaccesi, Pividori, & Johnson, 2004). By spatial cueing paradigm (Posner, Snyder, & Davidson, 1980) it is possible to study covert attention orienting. In this paradigm, a central face cue is presented with averted gaze. Shortly after that, a target appears in the cued direction or in the other direction. A participant's task is to respond to the target as fast as possible. Typically, response times to a target are faster when it appears in the cued side, as compared when appearing in the uncued side. This

difference in reaction times between cued and non-cued conditions signals covert attention orienting in the gaze-cued side (Driver et al., 1999; Friesen & Kingstone, 1998; Hietanen, 1999). It is suggested that this effect is automatic, exogenous and impossible to suppress (Driver et al., 1999). As an evidence for its reflex-like nature, it has been found to be very resistant to endogenous control. Driver and colleagues (1999), in one of their experiments, informed participants that target was four times as likely to appear at the uncued side. Still, under this condition, facilitation of attention orienting was found for the cued side.

### 1.3. Eye contact

Encountering a direct gaze is shown to facilitate many perception-related mental processes, such as the implicit memorization of faces (Mason, Hood, & Macrae, 2004) and gender-categorization (Macrae, Hood, Milne, Rowe, & Mason, 2002). Only four-month-old infants remember faces they have seen with a direct gaze better than they remember faces with an averted gaze (Farroni, Massaccesi, Menon, & Johnson, 2007). Faces and eyes with direct gaze are also detected more efficiently (Conty, Tijus, Hugueville, Coelho, & George, 2006; von Grünau & Anston, 1995) in a sense that detecting a face or eyes with a direct gaze among distractors is faster than detecting a face or eyes with gaze averted. The presence of direct gaze can also slow down mental processes when attention should be focused away from the eye gaze. Senju and Hasegawa (2005) showed that the detection of peripheral targets becomes slower when direct gaze is present. In an experiment by Conty, Gimmig, Belletier, George and Huguet (2010) it was shown that encountering an eye contact weakens the performance in a Stroop-task. It can be inferred that an eye contact holds attention, recruits cognitive resources, and that these effects are automatic or at least difficult to refrain from. The effect that eye contact has to humans has been called as the "eye contact effect" (ECE) (Senju & Johnson, 2009).

Eye contact elicits also many physiological responses. Skin conductance response (SCR) is indicative of autonomic arousal being sensitive to stimulus intensity and significance, and reflecting, thus, emotional and attentional processes (Dawson, Schell, & Filion, 2000). SCR is more related to the psychological significance of the stimuli than to their physical features (e.g. the intensity of colors) (Fowles, 1986) and this makes SCR a good measure of arousal in psychophysiological experiments. As early as 1971 it was observed in an experiment that seeing another person's direct gaze elicits stronger skin conductance responses compared to seeing averted

gaze (Nichols & Champness, 1971). However, many later studies have found only marginal effects of gaze direction on arousal (Donovan & Leavitt, 1980) or no effects at all (Kampe, Frith, & Frith, 2003; Martin & Gardner, 1979).

By measuring cardiac activation one can draw inferences on perceptual processing (Bradley, 2009). Heart rate (HR) deceleration is thought to index enhanced environmental detection, whereas HR acceleration is associated with environmental rejection (I. J. Lacey & Lacey, 1970). The degree of HR deceleration is susceptible to novelty and stimulus significance showing more deceleration to more novel and significant stimuli (Bradley, 2009). There are not many studies that have directly investigated the impact of gaze direction on heart rate. In one study, college women attempted to resolve a task while having either relatively intense gaze (85% of the time) or no gaze from a female confederate. The participants' heart rate was significantly lower when facing a direct gaze. This was interpreted to result from environmental intake when participants focused their attention on the gazing confederate and objects in the room (Kleinke, 1986).

Event-related brain potentials (ERPs) are signal-averaged electroencephalogram (EEG) recordings. They are small time-locked changes in EEG brought about by some internal or external events (Fabiani, Gratton, & Coles, 2000). There has been quite a lot of ERP-studies using face-images and also specifically faces with different gaze directions as stimuli. The early N170 component is widely investigated in face perception studies. Typically N170 amplitudes are larger to facial images compared to other stimuli and it has been suggested that the component reflects structural encoding of faces (Eimer, 2000). Gaze direction of static facial images does not usually have an effect on N170 amplitudes (Grice et al., 2005; Taylor, Itier, Allison, & Edmonds, 2001). However when using dynamic gaze shifts that establish gaze contact (or aversion) N170 is enhanced to direct gaze (Conty et al., 2007; Watanabe, Kakigi, Miki, & Puce, 2006). Conty and colleagues (2007) have also reported gaze direction modulation to ERPs between 160 and 210ms post-stimulus on centro-parietal sites that extends to occipito-temporal regions briefly after that, and enhanced frontal and parieto-occipital P300 components to direct gaze when using dynamic gaze shifts as stimuli. They suggested that the activity observed at centro-parietal sites reflects gaze direction sensitive activity distinct from N170 (Conty et al., 2007). The P300 component, on the other hand, seems to reflect enhanced attentive processing of emotionally and motivationally significant stimuli (Cuthbert, Schupp, Bradley, Birbaumer & Lang, 2000).

There is accumulating evidence linking gaze direction and basic motivational tendencies of approach and avoidance together (Adams & Kleck, 2003; Adams & Kleck, 2005; Hess, Adams, & Kleck, 2007). Direct gaze facilitates the processing and increases the perceived intensity of facially

communicated emotions of anger and joy (both associated with motivation to approach) whereas averted gaze facilitates the processing of fear and sadness (both associated with motivation to avoid). By recording frontal hemispheric activity with EEG it is possible to make inferences on motivational tendencies of approach and avoidance. Relatively stronger left-sided frontal activation is associated with approach-motivational system whereas relatively stronger right-sided frontal activation is associated with avoidance-motivation (Harmon-Jones, Gable, & Peterson, 2010). It would be, thus, expected to find that another person's gaze direction has an influence on the perceiver's frontal EEG asymmetry. Indeed, in an experiment by Hietanen, Leppänen, Peltola, Linna-aho & Ruuhiala (2008) relatively stronger left-sided frontal activation was observed when seeing direct gaze vs. averted gaze.

## 1.4. Eye contact with a person or a picture

Conventionally social perception has been viewed as a bottom-up process, where sensory analysis is completed unidirectionally (Allison, Puce, & McCarthy, 2000), although in last years this perspective has started to change slowly. Emphasis has been mostly in studying outcomes or operations of socially relevant visual tasks without taking into account the possible influence of higher-level feedback. Thoughts, expectations, knowledge or beliefs of the observer have not been given much attention even though they carry the potential of having an effect even on the basic perceptual processing (Teufel, Fletcher, & Davis, 2010). On the non-social field of visual processing, it is perhaps more widely acknowledged that all phases of information processing, starting from the primary visual cortex, are top-down influenced (for a review, Gilbert & Sigman, 2007). For one reason or another, when it comes to visual social cognition similar influences are not yet fully taken into account.

Most studies concerning face perception have been carried out by using pictures of faces as stimuli. However, when using pictures one clearly misses something important compared to a situation when another person is actually present. Facing a real person looking straight at you is likely to make you feel you are involved with that person and may evoke speculations about the reason for the gaze: "does that person know me?", "does he want something from me?", "does he think that I'm looking funny or strange?" or something else alike. Obviously this reaction does not occur when looking at a picture. Encountering a real person elicits typically a process of attributing mental states to him or her, a process termed usually as theory of mind (ToM). Interestingly Kampe,

Frith, and Frith (2003) showed that the same brain regions which activate when attributing mental states to others also activate when perceiving a direct gaze. It appears that when someone is looking directly at us, we automatically prepare for social interaction. Yet, little is known how this obvious difference between seeing a picture or a real person influences face and gaze processing, how early those influences may occur, and how profound they are.

There are some recent studies showing differences in physiological responses when facing a live person and a picture. In above mentioned study of Hietanen and colleagues (Hietanen et al., 2008) they used live faces and pictures of the same faces as stimuli. Faces were shown with different gaze directions in both conditions. As mentioned already, they found out that another person's direct gaze elicited relative left-sided frontal electroencephalographic asymmetry indicating a tendency to approach, and averted gaze resulted in relative right-sided asymmetry indicating motivational avoidance. Importantly these effects were present only when the participants were looking at a live person and not when looking at a picture. Subsequently the result was replicated by Pönkänen, Peltola, and Hietanen (2011). Additionally, in both studies, skin conductance responses were larger to direct gaze compared to averted gaze indicating stronger autonomic activation to direct gaze – but again only when looking at a live face. These results were interpreted as indicating the effect of mentalizing and processes of self-awareness when facing a real person.

Looking at a real face vs. a face picture or a dummy face elicits differences in event-related potentials also. The motivation-related early posterior negativity (EPN) has been shown to discriminate between a face of a dummy and a real face in a live condition but not when presented as pictures (Pönkänen et al., 2008). Subsequent results showed that direct gaze elicits greater N170 amplitudes and EPN potentials compared to averted gaze or closed eyes in a live condition, but not when seen as pictures (Pönkänen, Alhoniemi, Leppänen, & Hietanen, 2011). This experiment replicated the earlier results that N170 is not susceptible to different static gaze directions when presented as pictures, but proved that differences may be detected when using live humans as stimuli. These results suggest that not only the retinal image but also an observer's higher-state mental processes activated when looking at a real face vs. a picture can have a strong influence on perceptual processing at a very early stage of visual information processing.

## 1.5. Recent evidence on endogenous modulation of social perception

Recently, Teufel and colleagues conducted two experiments investigating top-down (or endogenous) modulation of social perception. First they studied how mental state attribution can influence gaze adaptation (Teufel et al., 2009). For coding of gaze direction, primate brain contains special neural mechanisms that are located in the superior temporal sulcus (STS) and adjacent areas (Allison, Puce, & McCarthy, 2000; Nummenmaa & Calder, 2009). Direct evidence for this was demonstrated by Perrett and colleagues who found individual cells in the STS area of macaque brain that are sensitive to different gaze directions (Perrett, Hietanen, Oram, Benson, & Rolls, 1992). Functioning of the gaze-direction perception mechanism can be investigated non-invasively using gaze-adaptation paradigm where the observer is adapted to faces gazing in a specific direction. After the adaptation phase, gaze-direction perception is biased towards the opposite side. This happens because the cells coding the adapted gaze direction reduce their responsiveness due to prolonged exposure. Adaptation effect therefore proves that different cell populations code different gaze directions. Teufel and colleagues measured the gaze direction adaptation in two different situations: 1) when the observer believed that the person he was watching was able to see and 2) when the observer believed that the watched person was not able see. They found that gaze adaptation was weaker in the latter situation.

Secondly Teufel and colleagues studied top-down modulation in covert attention orienting (Teufel, Fletcher, & Davis 2010). As already mentioned, seeing someone looking in a particular direction elicits a shift of attention in the same direction and this effect has been found to be automatic and impossible to suppress. (Driver et al., 1999; Friesen & Kingstone, 1998; Hietanen, 1999). Again, Teufel and his colleagues used two stimulus presentation conditions: 1) the observer believed that the person he was watching was able to see and 2) the observer believed that the watched person was not able to see. As expected, automatic attention orienting occured in a situation where the observer believed that another person was able to see. However, in a situation where observer believed that the other person's vision was blocked, gaze cuing was significantly reduced and could be voluntarily overridden. These two studies suggest that high-level mental processes, in this case the conception of another person's ability to see, can shape basic visual processes involved in gaze direction perception. These are conventionally taken to be more or less automatic and free from any effects of conscious processes.

## 1.6. About this study

In this study we wanted to further examine the effects of one's mental state attributions to cognitive and affective-motivational responses to another person's gaze. Especially we wanted to investigate the reasons for the differences that have been observed in many physiological measurements between the conditions where an observer sees a face of a live person and a picture of the same face. The main aim was to investigate whether the observer's belief of a gazer's ability to see him/her has an effect on the autonomic and brain responses to gazer's direct and averted gaze.

Participants sat at a table and viewed a face of a live model as a stimulus through a voltage sensitive liquid crystal shutter. Model had either a direct or averted gaze. Stimuli were shown in two different presentation conditions: 1) participant believing that the model can see him/her and 2) participant believing that the model cannot see him/her. The latter condition was created by using a special one-sided mirror –type of sheet, which allegedly allowed light to pass through it from the other side, but not from the other. We used an elaborate deception procedure to create a belief that such a sheet was placed between the participant and the model. By using this deception we were able to create a condition, where participants watched the face of a live model believing that the model was not able to see them.

We measured skin conductance responses (SCR), heart rate (HR) and frontal hemispheric asymmetry in the alpha band activity as well as event-related potentials (ERPs) in the electroencephalogram (EEG). ERP components under investigation were N170 amplitude, early parietal and centro-parietal activity and later frontal P3 component. We also measured subjective evaluations of arousal, valence, situational self-awareness and social presence.

We expected that the gaze direction would have an influence on the measured responses but that the differences in responses between two gaze directions are more prominent when participants believe that the model is able to see them. We expected the direct gaze to elicit larger SCR responses, more prominent HR deceleration and larger responses in all measured ERP components compared to averted gaze. We also expected that a direct gaze elicits relative left-sided frontal activity indicative of approach motivation whereas perceiving averted gaze elicits smaller left-sided asymmetry or even right-sided asymmetry indicating weaker approach motivation or even avoidance.

## 2. Materials and methods

### 2.1. Participants

The participants were 26 right-handed undergraduate students (14 female, mean age 23.0 years, range 19-43 years) with normal or corrected-to-normal vision. They gained a course credit or two movie tickets for participation. Informed, written consent was obtained from each participant prior to the experiment. Three participants (1 female, 2 male) were excluded from the analysis due to not believing in the mirror-deceit. Two participants (both female) were excluded due to not remembering the conditions during the experiment. Additionally one female and one male participant were excluded from the ERP-analysis and one male from the EKG-analysis due to technical error. Hence the final data sample consisted of 21 participants (11 female) for the SCR, frontal asymmetry and questionnaires data (SSAS, SAM and social presence form), 19 (10 female) participants for the ERP data and 20 (11 female) for the EKG data.

### 2.2. Stimuli

The stimulus was a face of a female experimenter. She assisted in the preparations of the physiological recordings, but all the instructions as well as information concerning the experiment were given by another experimenter. The model person bore a neutral expression and had a gaze either straight ahead or averted 30° to the left or right. Her face was presented through a voltage sensitive liquid crystal shutter custom-made for our laboratory. The liquid crystal shutter was attached to a black panel positioned between the model and the participant. The shutter switched between opaque and transparent states within 3 milliseconds. Shutter opening and closing was controlled by pc-computer with E-Prime 2.0 software, Psychology Software Tools. The size of the shutter window was 30 x 40 cm. The participant was seated at a distance of 60 cm from the shutter and the overall distance to the model sitting on the other side was 120 cm. Behind the model there was a white wall and the model wore a white shirt.
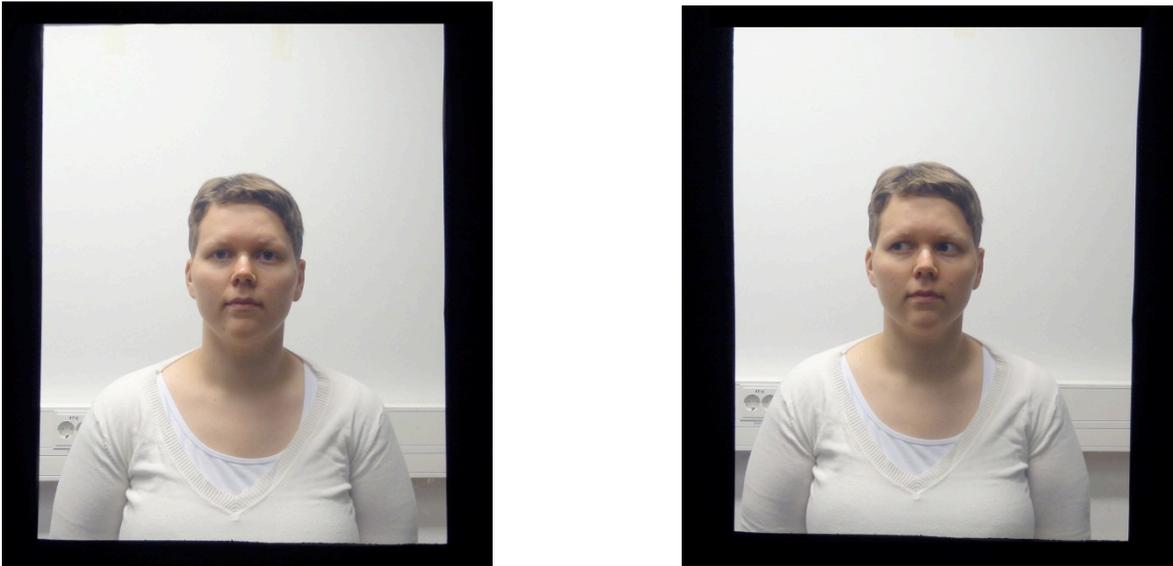
Figure 1. Examples of the face stimulus behind the liquid crystal shutter (in a transparent state): a direct gaze (left) and a left-averted gaze (right).

## 2.3. Experimental procedure

Experiment was conducted in two separate blocks: one for the condition where participants knew that the model was able to see him/her through the transparent sheet and another where they believed that the vision of the model was blocked (when it actually was not). The participants' view (in a sense of retinal image) was identical in the two conditions. The deceit was carried out by introducing a "special" one-sided mirror –type of a sheet to the participants. It was told to block the light from the participant's side thus preventing the model to see through it. First, a transparent sheet with thin black frame was slid between the participant and the model so that the participant saw that something really was added. The participant was told that the construction of the sheet was such that light only penetrates it from the model's side to the participant's side but not the other way. To demonstrate the blocked vision from the model's side, the participant was then taken to the other side of the shutter. During the walk around a short partition, another, opaque, sheet was quickly placed in front of the shutter. The participant then saw this latterly added sheet with a lattice-reminiscent aluminum-coloured surface that clearly was opaque. When the participant was returning back to his/her own side of the table, the opaque sheet was cautiously and quickly removed.

These two presentation conditions will be referred to as ST-condition (See Through) and BV-condition (Blocked Vision). The order of the presentation conditions (BV-condition / ST-condition) was counterbalanced across the participants.

Within each block, two series of measurements were conducted. The first series consisted of 16 trials. On eight trials the gaze was direct and on remaining eight it was averted to left or right. The presentation order of stimuli was pseudo-random (no more than two consecutive trials of the same type). The stimulus duration was 5 s with inter-stimulus interval (ISI) varying between 20 and 45 s. The length of ISI was controlled by the experimenter who was monitoring the level of SCR and allowing the next trial after recovery from the previous response. During ISI the shutter remained opaque. After the first eight trials, a short break (1-2 minutes) was allowed so that the participant had a chance to rest a while.

Before proceeding to the second series of trials, participants had again a chance to have a short break and they were informed about the upcoming change of trial length and number. The second series of measurement consisted of 160 trials. Of the trials, 80 were with direct gaze and 80 with averted (left or right). The duration of stimulus presentation was 0,5 s with 1,5 s ISI. The stimuli were presented in 10-trial sequences repeating the same gaze direction and after each sequence there was a 15-s break. The order of the sequences was pseudo-randomized so that no more than two sequences of the same type was allowed. A short signal was given through speakers 5 s before the start of next sequence of trials to alert the participant and also the model behind the shutter. After the first 80 trials participants were allowed a 1-2 minute break. During the ISI and the breaks the shutter was opaque.

After each block, participants completed a number of self-assessment questionnaires. The self-assessments were made only to direct gaze of each presentation condition. The participants were shown a face with a direct gaze for 5 seconds and then asked to fill the questionnaires. First the participants were asked to fill a short self-assessment manikin form (SAM) (Bradley & Lang, 1994) with two sets of 9-point scales (valence and arousal) to assess affective response to stimuli. Secondly participants were asked to fill a nine-item situational self-awareness scale (SSAS) (Govern & Marsch, 2001). The SSAS questionnaire included three factors which all were measured with three questions. Factors were public self-awareness (e.g. right now I'm concerned about the way I present myself), private self-awareness (e.g. right now I'm aware of my innermost thoughts) and awareness of immediate surroundings (e.g. right now I'm conscious of what is going on around me). Thirdly, participants were asked to fill a social presence form (SPF) (Short, Willams, &

Christie, 1976) with an extra item adopted from supplements made by Salinäs (I felt very much socially present – I didn't feel socially present at all) (Salinäs, 2005). Last two forms used 7-point scales.

To all questionnaires, participants were instructed to answer based on their feelings during the previous experimental block, not how they feel in general or at this point of their lives.

After coming to laboratory, participants were informed about the general procedure and a written consent was obtained. They were explained that physiological reactions would be measured while they saw a face of a female experimenter. After preparations for physiological measurements participants were introduced to the functioning of the shutter and instructed to sit relatively still during the experiment. They were told that their task was simply to watch the face of the female experimenter while the shutter was open. Two participants were excluded from the analyses when admitting after the BV-condition that they had forgotten that the stimulus person could not see them. After the experiment, participants were asked (both orally and in writing) about their feelings during the experiment and especially about differences between the stimulus presentation conditions. This was done to find out if the participants had any suspicion of deceit. In the end, the deceit was unveiled during debriefing and the participants were asked directly if they had any doubts about stimulus person seeing them during the BV-condition block. The participant was excluded from the analysis if he/she expressed doubts of deceit about blocked vision in all three occasions (oral and in writing prior the unveiling of the deceit, and oral after the unveiling of the deceit). Three participants were excluded due to expressing doubts of deceit.

## 2.4. Acquisition of the physiological data

Continuous EEG was recorded from 64 sites using actiCAP active electrodes. The signal was amplified with quickAmp amplifier (Brain products, Gilching, Germany) and average-referenced. 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.

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

heart rate (HR) measures two electrodes (Ag/AgCl) were placed on both arms. A suitable electrode-paste was used for both pairs of electrodes. The sampling rate for the digitized signals was 1000 Hz.

All physiological data collection was controlled with Brain Vision Professional Recorder running on a PC-computer.

## 2.5. Data Analysis

All statistical analyses were conducted using repeated-measures analysis of variance (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.

### 2.5.1. SCR-analysis

The SCR data were re-sampled offline to 100 Hz and filtered with 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 after 1 s from the stimulus onset. If the maximum amplitude was negative, it was set to zero. In case there was more than 0.1 μS amplitude rise during the first second after stimulus onset, the trial was rejected. In this case the response was too early for being elicited by the gaze-stimulus. Of all trials, 7.7% was eliminated due to this criterion or because of technical error. The data were averaged for each condition and gaze direction for each participant, including those trials with zero response. This method of calculation is referred as the magnitude of galvanic skin response. To normalize the data for statistical analysis, a logarithm-transformation was performed. Finally an ANOVA was carried out with condition (BV-condition, ST-condition) and gaze direction (direct, averted) as within-subjects factors.

*2.5.2. HR-analysis*

Electrocardiogram (ECG) was analyzed offline with in-house (Matlab based) algorithm to measure the time intervals between two successive R-waves (interbeat interval, IBI). After computer based detection of R-peaks, the data were manually checked and corrected in case of falsely detected or missing peaks. 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. This was done by averaging the IBIs in each interval weighted by the proportion of the interval occupied by that beat. 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 bpms of each post-stimulus 1 s interval from the baseline. Thus negative change score values indicate HR deceleration and positive values HR acceleration. For statistical analyses a logarithm transformation was performed to normalize the data. An ANOVA was then carried out with presentation condition (ST-condition, BV-condition), gaze direction (direct, averted) and time (0-1, 1-2, …, 9-10 s) as within-subjects factors.

*2.5.3. ERP-analysis*

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 Gratton/Coles –algorithm and manually checked for artefacts. Trials containing artefacts were rejected. In order to study 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.

Following Conty, N'Diaye, Tijus and George (2007) we were interested in near-midline parietal and centro-parietal activity shortly after the N170 response. Visual inspection showed very similar activity over the whole area and we decided to pool over all six electrodes (C1/CP1, Cz/CPz, C2/CP2). We measured the mean amplitude between 180 and 300 ms separately for each participant in each condition. Statistical analysis was performed with 2 x 2 ANOVA with presentation

condition (ST-condition, BV-condition) and gaze direction (direct, averted) as within-subject factors.

Furthermore we analyzed the frontal P300 component. Visual inspection showed that differences were most salient on anterior frontal and frontal pole sites. Therefore, we analyzed right and left anterior frontal and frontal pole regions (over electrodes AF4/3, AF8/7 and Fp2/1) measuring the mean amplitude between 200 and 450 ms for each participant in each condition. A 2 x 2 x 2 ANOVA was then carried out with presentation condition (ST-condition, BV-condition), gaze direction (direct, averted) and hemisphere (left, right) as within-subjects factors.

Finally for the N170 analysis, we pooled 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 of N170 were then identified within time window of 110-180 ms for each participant in each condition. For these measurements, also a 2 x 2 x 2 ANOVA with presentation condition (ST-condition, BV-condition), gaze direction (direct, averted) and hemisphere (left, right) as within-subjects factors was carried out.

### 2.5.4. Frontal EEG asymmetry-analysis

The EEG-signal was offline referred to averaged mastoids and filtered with a 0.5 – 30 band-pass filter with 24 dB/oct slope on both ends. Signal was ocular corrected using Gratton/Coles - algorithm and segmented to 5-s epochs starting from the stimulus onset. Segments were manually inspected for artifacts and trials containing excessive artifacts were eliminated from further analysis (2.0% of trials). Spectral power density was calculated from segmented, artifact free EEG using fast fourier transform (FFT) with 75% periodic Hanning window. Trials were then averaged within each participant in each condition. Power density values within the alpha band (8-13 Hz) activity were calculated and logarithm-transformed to normalize their distributions. Asymmetry scores were calculated for electrode pairs at frontal (F6/F5, F4/F3, AF4/AF3) sites by subtracting the logarithm-transformed power density values of the left site from that of the right site. For the statistical analysis a 3 x 2 x 2 ANOVA was performed with electrode site, gaze direction (direct, averted) and presentation condition (BV-condition, ST-condition) as within-subject factors.

*2.5.5. Analysis of questionnaires*

The scores of three factors of SSAS, ratings of SPF and both ratings of SAM were analyzed independently and separately for two presentation conditions (BV-condition, ST-condition) using a t-test for paired samples.

## 3. Results

### 3.1. Skin conductance response

Figure 1 shows the mean SCR values in both presentation conditions and for each gaze direction. Overall responses were larger in ST-condition than the BV-condition. Additionally responses to direct gaze seemed to be larger compared to averted gaze, at least in the ST-condition. An ANOVA confirmed these observations by indicating a main effect for gaze ($F_{(1,20)}$ = 4.931, $p < .04$) and for presentation condition ($F_{(1,20)}$ = 5.396, $p < .04$). Importantly the interaction between the main effects was significant ($F_{(1,20)}$ = 5.817, $p < .03$). Pairwise comparisons indicated that the SCR was larger to direct gaze compared to averted gaze in the ST-condition ($t$ = 3.213, df = 20, $p < .01$) but not in the BV-condition ($t$ = .395, df = 20, $p$ = .70).
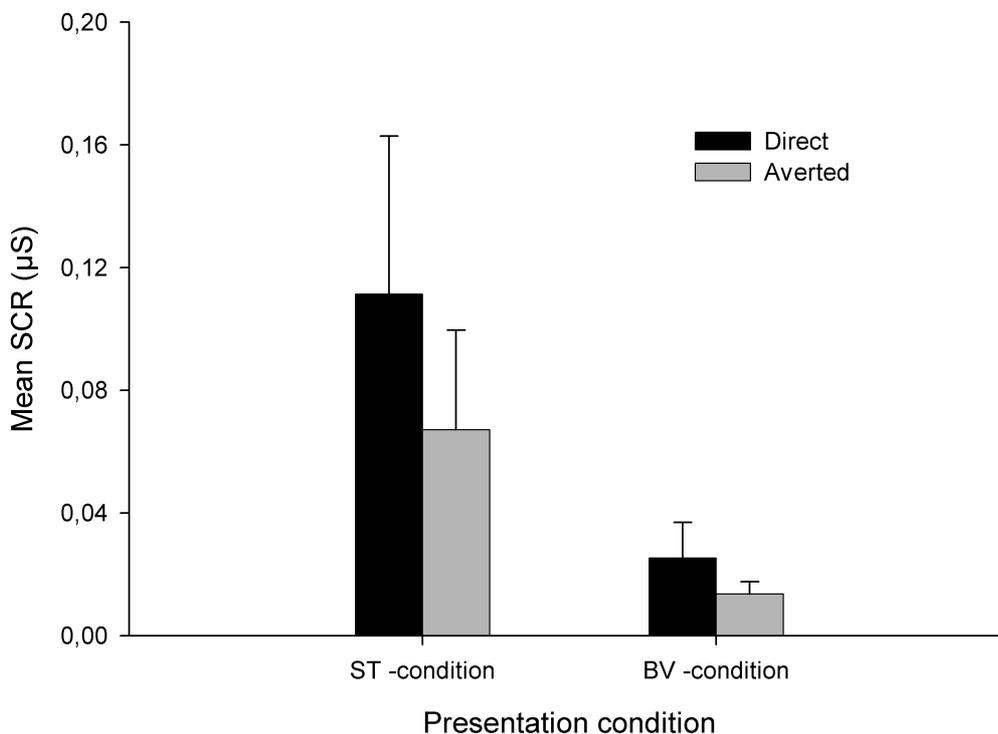


Figure 1. Mean skin conductance responses to direct and averted gaze in both presentation conditions (ST = See Through, BV = Blocked Vision).

## 3.2. Heart rate

The HR-change scores are presented in figure 2. The results showed a HR-deceleration response in all conditions. However, only in the ST-condition HR-deceleration was more pronounced for direct than averted gaze. An ANOVA revealed a main effect for gaze ($F_{(1,19)}$ = 4.710, $p < .05$) and time ($F_{(9,19)}$ = 36.358, $p < .001$) as well as an interaction of presentation condition and gaze ($F_{(1,19)}$ = 19.319, $p < .001$). When analyzing both presentation conditions separately, t-tests indicated that for ST-condition the HR-deceleration was more prominent for direct than averted gaze ($t$ = 2.659, df = 19, $p = .016$) but for BV-condition the difference was not significant ($t$ = 1.012, df = 19, $p = .32$).
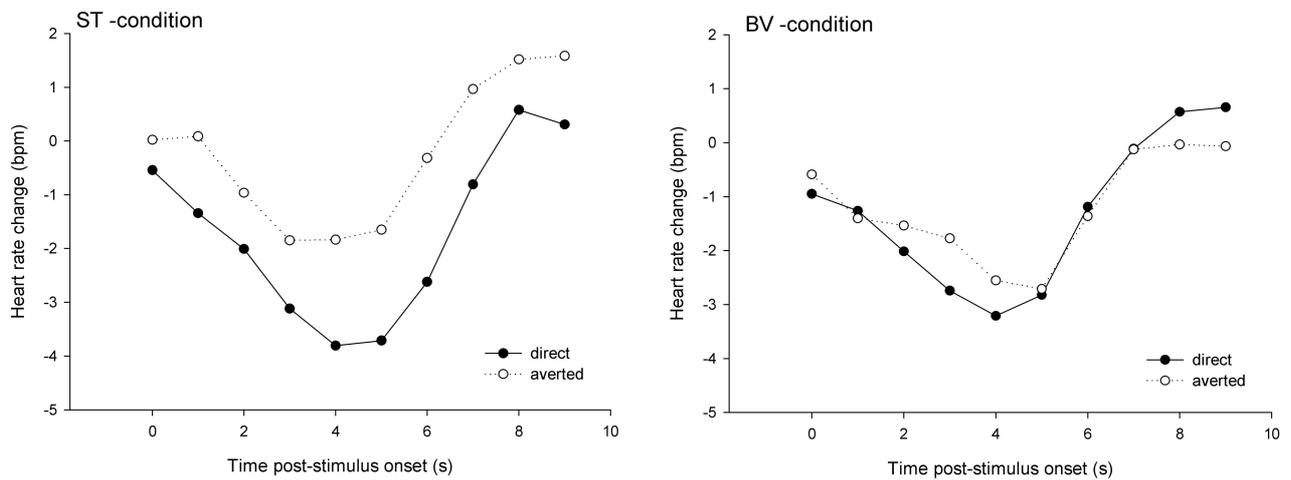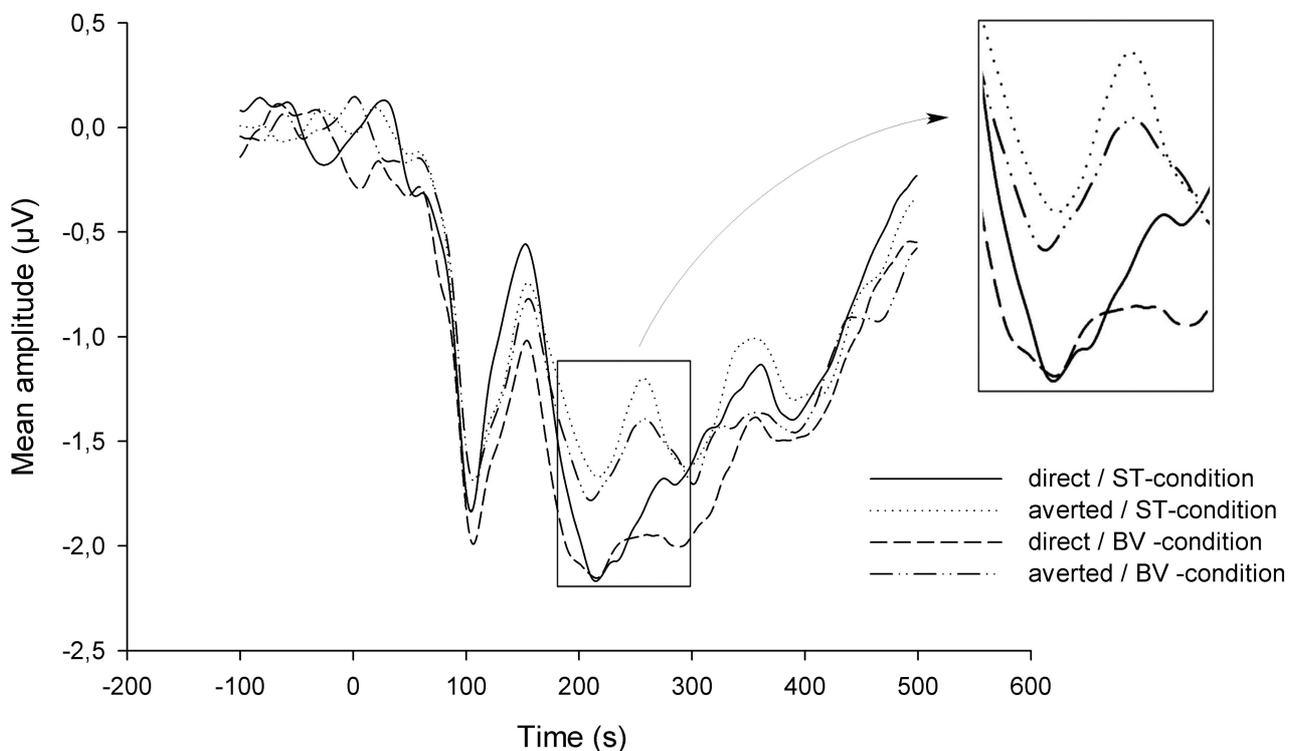


Figure 2. Average HR change scores to direct and averted gaze in both presentation conditions (ST = See Through, BV = Blocked Vision)

### 3.3. Event-related potentials

*N170 response.* For N170 ANOVA revealed no significant main effects or interactions (all *p*:s>.1).

*180-300 ms response.* For mean amplitude between 180 and 300 ms, an ANOVA revealed a main effect of the gaze direction ($F_{(1,18)}$ = 5.794, *p* < .05) reflecting that direct gaze induced a more negative response compared to averted gaze over parietal and centro-parietal regions. This effect was similar in both presentation conditions. Other effects were not significant. The grand-averaged ERPs are illustrated in Figure 3.



Figure 3. Grand averaged event related potential waveforms pooled over parietal and centro-parietal regions for direct and averted gaze in two presentation conditions (ST = see through, BV = blocked vision). The boxed area represents the time interval of interest between 180-300 ms.

*P3 response.* For mean amplitude between 200 and 450 ms (P3), an ANOVA revealed a main effect of gaze direction ($F_{(1,18)}$ = 8.737, *p* < .01) and hemisphere ($F_{(1,18)}$ = 37.010, *p* < .001) as well as an

interaction between gaze direction and presentation condition ($F_{(1,18)}$ = 5.648, $p$ < .05). The main effects reflected that frontal activation at fronto-polar and anterior-frontal sites was shifted in the positive direction for direct gaze compared to averted gaze and that activation was overall more negative recorded over the right than left hemisphere. For interaction between gaze direction and presentation condition, pairwise comparisons were performed to investigate the effect of gaze direction for both presentation conditions separately. For ST-condition, there was an effect of gaze direction ($t$ = 3.492, df = 18, $p$ < .01). The response was shifted in the positive direction to direct vs. averted gaze. However, for BV-condition, such an effect was not present ($t$ = 1.050, df = 18, $p$ = .31). The grand averaged ERPs are presented in Figure 4.
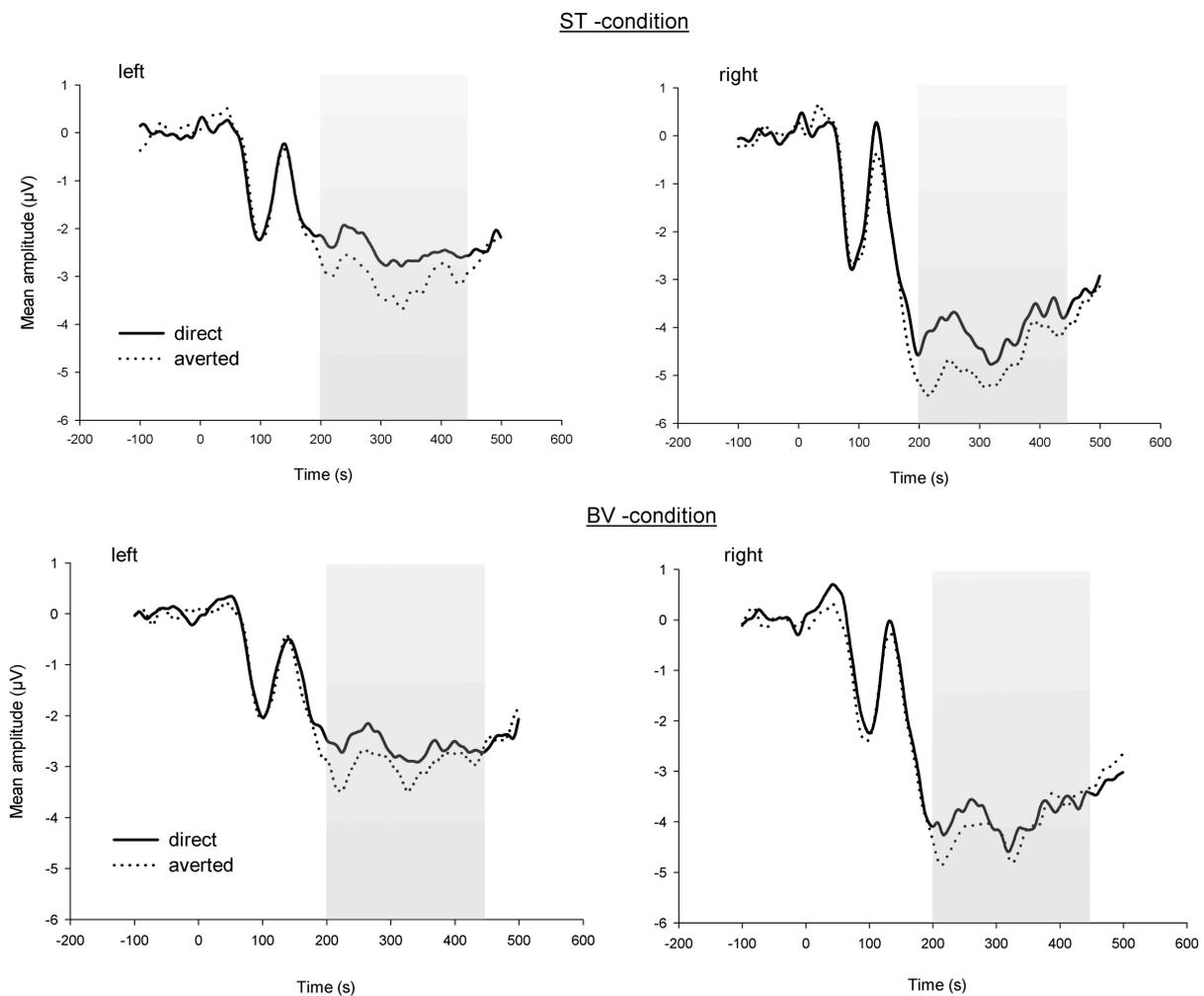


Figure 4. Grand averaged event related potential P3 waveforms pooled over anterior frontal and frontal pole regions for direct and averted gaze in two different presentation conditions (ST = See Through, BV = Blocked Vision). The shaded area represents the time interval of interest between 200-450 ms.

## 3.4. Frontal EEG asymmetry

An ANOVA did not show any significant main effects or interactions (all $ps > .1$). The results were similar when analyzing each electrode pair separately with 2 x 2 ANOVAs (presentation condition and gaze direction as within-subject factors).

## 3.5. Self-evaluations

For public self-awareness, a t-test indicated stronger reported public self-awareness in ST-condition than in the BV-condition ($t = 2.517$, df $= 20$, $p < .05$). Interestingly, for private self-awareness and awareness of immediate surroundings no significant differences were found (see table 1). For social presence ratings (see table 1), self-assessed social presence was stronger in ST-condition compared to BV-condition ($t = 3.104$, df $= 20$, $p < .01$). For two SAM-ratings (valence and arousal), no significant differences were found between the two presentation conditions (mean arousal ratings were $M_{ST} = 2.95$ and $M_{BV} = 2.62$, and mean valence ratings $M_{ST} = 5.95$ and $M_{BV} = 6.52$)

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

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

# 4. Discussion

The main aim of the present study was to investigate whether the observer's belief of a gazer's ability to see him/her has an effect on the autonomic and brain responses to gazer's direct and averted gaze. A live model was used as a stimulus and the model's face was presented through a liquid crystal shutter. In the experiment, two different presentation conditions were used. In one condition, the model was able to see the participant, whereas in another condition, the participant was led to believe that the model's vision was blocked. The purpose of the two presentation conditions was to manipulate the mental attributions of the participants. The participant either believed that he/she is also being looked at by the model or that he/she is not looked at. As dependent variables we measured skin conductance responses (SCR), heart rate (HR), three face sensitive components of event related potential (ERP), power in the alpha-band EEG activity from three left and three right frontal channels (F3, F5, Af3 / F4, F6, Af4), and subjective ratings of situational awareness, social presence, arousal and emotional valence.

The results unveiled an interplay between gaze direction and mental attributions affecting many physiological responses. Skin conductance responses and heart rate deceleration were larger for direct gaze than for averted gaze, but only when the participant believed that the model could see him/her. For brain responses, the relatively early N170 ERP component did not show any differences between direct and averted gaze in either presentation conditions. However, the other early component measured from parietal and centro-parietal regions during the time interval 180-300 ms discriminated between the direct and averted gaze. And noteworthy, this discrimination was observed in both presentation conditions. Instead, the late ERP component P3, measured from anterior frontal and fronto-polar regions showed more positive responses to direct gaze, but only when the participants believed that they were being watched by the model. Measures of asymmetric frontal alpha band activity did not show any differences between the gaze directions or between presentation conditions. Subjective ratings showed higher levels of self-awareness and social presence when the model was able to see the participant. This is in line with the SCR-, HR- and P3 results of the present study.

In several early studies, it has been shown that direct gaze elicits stronger autonomic responses compared to averted gaze (Kleinke & Pohlen, 1971; Nichols & Champness, 1971; Strom & Buck, 1979). Nevertheless, there are also many studies where such differences have not been found (Joseph, Ehrman, Mcnally, & Keehn, 2008; Kampe, Frith, & Frith, 2003; Kylliäinen &

Hietanen, 2006). Hietanen and colleagues (2008) showed that larger responses to direct vs. averted gaze were present only when looking at a real person, not when looking at a photograph, and they interpreted their results as suggesting the effects of mentalizing and self-awareness when being looked at by a real person. The present results provide strong support for such interpretation and build evidence on the claim that autonomic arousal elicited by somebody's direct gaze is, perhaps, more of a result of higher state mental processes rather than a low stage or even an automatic response to a retinal image of a face with eyes pointing at the observer's direction.

The possibility for an automatic autonomic arousal was recently studied in an experiment where faces with different gaze directions were presented in the background while the participants were carrying out a cognitively demanding word spelling task at the same time (Conty et al., 2010). Stronger SCRs were found in direct vs. averted gaze condition. The authors interpreted this as an evidence of functioning of a fast-track subcortical route (Senju & Johnson, 2009), responsible of fast, automatic reactions to a direct gaze. It is assumed that this subcortical face detection pathway involves superior colliculus, pulvinar, and amygdala (see also, Johnson, 2005). It is further hypothesized that this pathway operates on low spatial frequency, modulates the cortical responses to faces and is susceptible to contextual modulation given by task demands and social context. (Senju & Johnson, 2009).  While it seems plausible, that heightened SCRs to direct vs. averted gaze in Conty and colleague's (2010) experiment during word spelling task were due to functioning of such a route, there is, however, another possible interpretation for the results. The heightened autonomic arousal to direct gaze may have been related to the stress caused by the inhibition of averting the attention from the primary visual task to the face with direct gaze. As cited already in the introduction, it has been shown that direct gaze captures and holds attention and that this effect is difficult to refrain from (Senju & Hasegawa, 2005; Conty et al., 2010). However, one could argue that we have also a tendency to allocate attention to a cued direction of averted gaze. In this case, the participants would also have inhibited their attention from re-orienting from the primary task and increased SCRs would have been expected. Nevertheless, this orienting effect is short lived and declines between 150 ms and 300 ms (Frischen, Bayliss, & Tipper, 2007). In the experimental paradigm of Conty et al. (2010), the word spelling task began 500 ms after presenting the face and, thus, in the averted gaze situation, the tendency to allocate attention to cued direction did not overlap with the word spelling task. It is possible that the results by Conty and colleagues simply reflect the increased stress level when actively inhibiting the tendency to attend to a direct gaze while carrying out a cognitively demanding task. Neither interpretation, theirs or the one suggested here, contradicts the findings of this study, but when evaluating the roles of automatic and higher

state (or subcortical and cortical) influences on autonomic arousal it becomes important to distinguish between the two. In the light of the present results, it seems that autonomic arousal to direct gaze is linked to the knowledge of being looked at by someone and the possible functioning of the subcortical fast-track route is overrun by cortical processes.

Interestingly the subjective arousal and valence ratings did not differ between the two presentation conditions. In an earlier study by Hietanen et al. (2008), similar ratings were measured to different gaze directions in a live vs. pictorial conditions. They found higher overall rates of subjective arousal in live the condition (M = 4.4) compared to the pictorial condition (M = 2.8). In the present study, the subjective arousal ratings were approximately similar across presentation conditions ($M_{ST}$= 2.95 vs. $M_{BV}$=2.62). Thus, subjective arousal ratings in this study gained clearly lower ratings compared to the live condition in the study by Hietanen et al. (2008). This may explain the discrepancies between this study and the earlier results in N170 amplitude and frontal alpha-band asymmetry. As argued by Conty et al. (2010) if live and pictorial stimuli are presented in the same experimental session, the live stimuli may become especially salient and relevant to the participant.

The N170 amplitude did not differentiate between gaze directions or presentation conditions in this study. There may be several reasons for this. It has been acknowledged that N170 is not sensitive to different gaze directions of static face images (Grice et al., 2005; Taylor, Itier, Allison, & Edmonds, 2001), although marginal differences have been found in some studies (Watanabe, Miki, & Kakigi, 2002). However, when using dynamic gaze shifts, enhanced responses have been found more consistently to direct gaze (Conty, N'Diaye, Tijus, & George, 2007; Watanabe, Kakigi, Miki, & Puce, 2006). In one recent study, N170 responses were stronger to static direct gaze compared to static averted gaze when using live models as stimuli (Pönkänen, Alhoniemi, Leppänen, & Hietanen, 2011). In line with majority of the previous studies using static face stimuli, Pönkänen and colleagues found no differences when using photographs of faces with direct or averted gaze. A possible reason for the lack of gaze direction effect in the present study may be related to differences in experimental paradigm. In our study, only a live model was used as a stimulus, whereas in the aforementioned study a live model and pictorial stimuli were used in the same experiment. As discussed above, this may have caused the live model condition to become especially salient and meaningful to the participant, and perhaps enhanced the early N170 response to direct gaze of live face. This seems plausible, given that N170 is sensitive to socially relevant

facial information such as emotional expression (Blau, Maurer, Tottenham, & McCandliss, 2007) and familiarity (Caharel et al., 2002).

Another early component was measured from parietal and centro-parietal regions in the time interval of 180-300 ms. For this component, direct gaze caused more negative waveform regardless of presentation condition. A similar effect has been found earlier for dynamic gaze shifts and it has been suggested to be a gaze sensitive response independent of N170 (Conty et al., 2007). The results of the present experiment give support for these findings. Noteworthy, in the present experiment, gaze sensitive parietal component was observed in the absence of N170 gaze sensitivity. The present results show that this early parietal and centro-parietal response differentiates between different gaze directions not only in the case of dynamic gaze shifts but also when viewing static faces, at least when presented live.

The P3 component measured from the anterior frontal (AF) and fronto-polar (FP) regions in the time interval of 200-450 ms was stronger for direct gaze. The most interesting aspect is, perhaps, the fact that differences were observed only in the situation when the participant knew that he/she was being looked at by the model and not when participant thought that the model's vision was blocked. Very similar waveform differences from the same locations were observed by Bobes, Quiñonez, Perez, Leon and Valdés-Sosa (2007) in a study on visual and emotional memories for faces. They used an oddball paradigm with unknown faces as standard stimuli and either newly learned faces or faces of acquaintances as target stimuli. They found an early P3 component on the AF and FP regions that was observed only to faces of acquaintances but not for unknown or newly-learned faces. They interpreted this to reflect fast activation of emotion-from-identity memory (identity-related emotional recollections) and suggested that emotional-social information can elicit fast and automatic assessments (indexed by similar frontal component observed in this study) crucial for successful social interactions. The present results give a reason to speculate that, perhaps, this early frontal component is not so much (or at least not only) a consequence of activation of memory traces concerning previously known individual, but rather an index of activation of brain structures related to social interaction. In Bobes' and her colleagues' work (2007), early positive response was observed when showing pictures of people with whom participants had a history of social interaction. In this study, a similar response was observed in a situation that involved a potential for social interaction (when participants believed that the model can see him/her, and the model had a direct gaze). This is, of course, just a speculation and more research is needed to solve this issue. Another matter worth mentioning concerns the onset latency of the P3 component. As Bobes et al. (2007) suggested, it can provide a lower bound to the

availability of the memory trace. By applying the same reasoning here, the onset latency may provide a lower bound for a brain to react to a situation containing elements of social interaction. In this study differences started to emerge around 200 ms, which is in accordance to the evolutionary considerations suggesting that brain areas handling emotionally and socially relevant information should activate rapidly (Phelps, 2006).

Measures of asymmetric alpha band EEG activity in the frontal sites did not show any significant effects of gaze direction or presentation condition. Earlier studies using live models reported stronger relative left-sided activation for direct vs. averted gaze (Hietanen et al., 2008; Pönkänen et al., 2011). Left sided alpha band asymmetry has been associated with a tendency to approach and relative right-sided activation with an avoidance motivation. However, in a recent study using live models, such asymmetry differences were not found (Pönkänen & Hietanen, 2012). The reason for such discrepant results was not clear but the authors suggested that issues related to dominance effects and social connectedness due to prior social interaction may have had an effect on the results. They proposed that the prior interaction between the model and the participant – are they introduced, do they shake hands or talk with each other, how authoritative or equal the model seems to be compared to participant in the situation, and so on – may be crucial for motivational brain responses. In this study the negative result may result from several reasons. First, in both of the two earlier studies with positive results, the paradigm involved live and pictorial stimuli. As suggested above, an experiment that includes only live stimuli does not perhaps emphasize the meaningfulness of the real person as strongly as when presenting pictorial and live stimuli in the same experiment. This may lead to lowered affective responses and may consequently result in lowered motivational tendencies to approach or avoid. Second, similar reasons that were suggested to cause negative results in the study of Pönkänen and Hietanen (2012), namely dominance or social connectedness effects, could have caused the lack of asymmetry result in the present study. Thirdly, it is possible that facial attributes, or other personal qualities of the model may evoke differential affective reactions in different participants, which in turn may interact with motivational tendencies to avoid or approach.

In two studies, Teufel and his colleagues (Teufel et al., 2009; Teufel, 2010) were able to show that mental attributions have an influence on basic visual perceptions. They found evidence that gaze cueing and adaptation effects are modulated by what the observer believes about the other's mental state. They argued that perceptually available information is often insufficient for maximally adaptive behavior. Following one's gaze, for example, is highly adaptive because it can expose information about the gazer's preferences, goals, and intentions. But knowing that the gazer is blind

changes the situation radically and makes gaze following in that situation maladaptive. In Teufel's and his colleagues view, a range of variables, such as identity of the social agent, sociocultural context and interaction history, must be used to supplement perceptual information. This would make the perception process integrative, where bottom-up information provided by stimulus is modulated by top-down information regarding contextual factors. The results of this study bring further evidence for such a view. The data provided here suggests that SCR and HR responses, and even some early brain responses are modulated by the mental state attributions, in this study, the belief about somebody's ability to see. These findings are in line with a prediction of the fast-track modulator –model (Senju & Johnson, 2009) suggesting that fast-track modulation can be overcome by other sources of modulation, such as top-down information. This study cannot provide any evidence of the existence of fast-track modulation, but it provides strong evidence for higher order influence. The present results show that such top-down influence can overcome automatic autonomic responses to direct gaze. Given that autonomic reactions are relatively slow and long lasting (compared to fast brain responses, for example) cortical control makes perfect sense. Reading a newspaper would be tiresome if our autonomic system would react strongly each time we see a face looking at us (at camera). And on the other hand, it would be potentially harmful if it did not react when we see someone looking at us when walking down a street.

Most studies on social cognition use pictorial stimuli in experiments. While pictures can exhibit similar perceptual properties as real people, it seems that they do not trigger similar reactions as real people. It is unclear to what amount the results from the pictorial experiments are applicable to conditions where real people are present (and vice versa). It may even be that looking at a real person triggers qualitatively different sociocognitive processes compared to looking at a picture or an animation (e.g. Skarratt, Cole, & Kingstone, 2010). While one solution to this problem can be the use of video clips and deception procedure (Teufel et al., 2009; Teufel, 2010), perhaps the most applicable is the use of real persons in a controlled manner as was done in this study and previous studies in our laboratory. Of course, one must confess that the control of the stimuli is especially problematic when using real people as stimuli. Then again when studying social vision one must ask whether it is better to slightly give up in stimulus control than possibly to throw away phenomena which may appear only when encountering another human being. This choice can have a huge impact on results, as indicated by this study and previous studies using live models.

One weakness of this study was that only one model was used as a stimulus person. This leaves a possibility that individual features of the model's face or eyes may have had an effect on results. When using live models as stimuli, the number of faces that is practically possible to use in

one experiment is naturally more limited than when using pictures or video clips. However, when using two or three different models instead of one, the risks of having strong effects due to individual features are much smaller. The possible influence of sex of the model is also interesting. In the study by Pönkänen et al. (2011), frontal alpha-band asymmetry was observed only when using a female model, but not when using a male model. It is unclear, of course, whether the difference was due to sex or to other differences between the models. In the future studies using live models these issues should be taken into consideration.

Another possible weakness of the present study was related to the length of the experiment. Because we wanted to collect autonomic responses and ERPs in the same study, we had to carry out two series of measurements in each block. Therefore made the experiment took 1-1,5 hours, after a half an hour preparation procedure. It is obvious that the participants were a slightly tired when carrying out the last series of measurement. However, because the presentation order of the blocks was counter-balanced, there was no danger of systematic bias. Nevertheless, tiredness of the participants may have caused diminished responses and, thus, lowered the statistical power of the experiment.

For future studies, it would be interesting to investigate what kind of a role the eyes play in eliciting the observed differential responses. Seeing another person's eyes pointing towards us is a salient and significant stimulus, influencing perceptual and cognitive functions as well as brain and autonomic responses (Senju & Johnson 2009). However, it would be interesting to study if another person's direction of overt attention influenced the responses even in the case when the eyes are not visible at all. For example, would we observe differences in autonomic responses between seeing another person with his/her head directed to us vs. rotated laterally if this person wore dark sunglasses. This line of thinking can be taken even further. Would it be possible to observe differential psychophysiological responses to another person's direct vs. averted attention in the case where the observer knows that the other person is looking at him/her or not, but the observer cannot see the gazer at all. Diving deep into these questions would provide precious information about visual social perception and the effects of mental attributions on it.

As a conclusion we summarize that the results of this study indicate that higher level processing such as mental attributions can have a profound influence to responses to eye contact. This influence extends to autonomic and brain responses and it is perhaps more prominent than conventionally taken into account.

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