

The observer observed: Frontal EEG asymmetry and autonomic responses differentiate  
between another person's direct and averted gaze when the face is seen live

Laura M. Pönkänen \*, Mikko J. Peltola, and Jari K. Hietanen\*

<sup>1</sup>Human Information Processing Laboratory, School of Social Sciences and Humanities, FIN-  
33014

University of Tampere, Finland

Pages: 34

Tables: 1

Figures: 3

\*Correspondence concerning this article should be addressed to Laura Pönkänen (e-mail:  
[laura.ponkanen@uta.fi](mailto:laura.ponkanen@uta.fi); tel. +358-3-3551 7966; fax. +358-3-3551 7345) or to Jari Hietanen  
(e-mail: [jari.hietanen@uta.fi](mailto:jari.hietanen@uta.fi); tel. +358-3-3551 7720; fax. +358-3-3551 7345) at School of  
Social Sciences and Humanities, FIN-33014, University of Tampere, Finland.

### Abstract

Recently, we showed that another person's gaze direction influenced the perceiver's frontal EEG asymmetry and autonomic arousal in response to freely viewed real faces, but not in response to face pictures. However, the lack of a task during the viewing may have resulted in less attention allocation to face pictures vs. live faces. In the present study, the participants performed two online tasks while viewing the faces presented live through an electronic shutter and as pictures on a computer screen. The results replicated those from our previous experiment showing that direct gaze elicited greater relative left-sided frontal EEG asymmetry and autonomic arousal than averted gaze but, again, only in the live condition. However, the results also showed that two live stimulus faces (male and female) elicited differential EEG asymmetry responses in our participants (all females), and the effects of gaze direction were observed only for the (live) female faces. The results suggest that the discriminative responses to live faces vs. pictures are likely to reflect the participants' enhanced mental-state attributions and self-awareness when looking at and being looked by live faces. Thus, the motivation- and affect-related psychophysiological responses to gaze direction are most discriminative in the presence of another person, regardless of whether the face/gaze is actively monitored or not.

*Keywords:* Motivation, Gaze direction, Face perception, Electroencephalography, Social Cognition

## 1. Introduction

The vast development of computer- and video-mediated communication devices has allowed two people to effortlessly engage in face-to-face interaction without being physically near each other. Current research also shows that impressions given through computer-mediated communication approximate those given in live interaction (Weisbuch et al., 2009). How can it be explained, then, that only a minority of significant decisions related to other people, for instance, whom one is going to hire or marry, are currently based on interaction conducted by virtual means? Apparently, something is lost in transfer when people do not share the same physical space when communicating with each other. Smooth and efficient interaction between people requires accurate perception of a host of different types of nonverbal cues. Gaze direction seems to have an important role in gathering socially relevant information from other people (George & Conty, 2008; Kleinke, 1986). Monitoring of others' gaze is needed especially in the initiation of interaction, as it aids in defining the nature of dyadic relations (Exline et al., 1965) and motor plans (Nummenmaa et al., 2009) in the first place. If the other person's gaze is turned away, it is likely to be seen as an act of aversion, whereas seeking of an eye contact is usually seen as a gesture of approach. Although these action tendencies can be communicated to some extent in virtual interaction, meeting the eyes of a person present in the same space is likely to elevate the anticipation of the other person's likely next actions and the urge to evaluate the consequences of these actions, and heighten the sense of reciprocal involvement.

In recent experiments, we have measured brain responses and autonomic responses to facial stimuli differing in preparedness for social interaction. These stimuli have been presented in two conditions, as pictures on a computer monitor and "live", referring here to a condition in which the stimulus person has been physically present and has shown his/her face through a computer-controlled liquid crystal (LC) window (e.g., Hietanen et al., 2008). The

results have shown greater visual event-related potentials (ERPs) to a human face vs. a dummy face (Pönkänen et al., 2008) and to a direct vs. an averted gaze (Pönkänen et al., in press), but only when the faces have been presented live through the LC window. In addition to these early-stage neurocognitive responses, Hietanen et al. (2008) showed that seeing another person's direct and averted gaze activates the motivational approach–avoidance brain systems, respectively, indicated by asymmetrical alpha power distribution in the frontal electroencephalography (EEG). There is a growing body of evidence showing that approach motivation enhances relative left prefrontal cortex activity and that avoidance motivation enhances relative right prefrontal cortex activity, regardless of stimulus valence (for a review, see Harmon-Jones et al., in press). Hietanen et al. (2008) also measured sympathetic arousal (skin conductance responses), considered to be a good index of the general energetic level (arousal) of behaviour (Andreassi, 2000), and showed greater arousal for direct gaze than averted gaze. Again, all these effects of gaze direction were observed only when the stimulus faces were presented live through the LC window. Thus, we suggested that when facing a live person, gaze direction is likely to play a greater role in influencing sensations of intimacy, experienced self-relevance, and awareness of how one is seen by another person who is physically present, as compared to seeing a picture of a face on a computer screen (Hietanen et al., 2008; Pönkänen et al., in press).

However, there are several, different types of behavioral and neurophysiological studies showing gaze direction effects also when pictures or animations of faces are used as stimuli. Notably, in many of these studies (i.e., Conty et al., 2007; Mason et al., 2005; Sato et al., 2008; Schilbach et al., 2006) discrimination of gaze direction or some other explicit task related to face categorization was employed. In our aforementioned studies, instead, the faces were observed without a concomitant task (Hietanen et al., 2008; Pönkänen et al., in press; Pönkänen et al., 2008). Thus, the question arises, whether the lack of a task, related to the

gaze direction or not, might have contributed to the lack of gaze direction effects in the picture presentation mode in these studies.

There are several ways in which the presence of a concomitant task may contribute to the differing neurocognitive and motivational responses to gaze direction when faces are presented live vs. as pictures. With even a simple task, the participants' focus is directed according to the task requirements, whereas in free viewing of the face stimuli the participants' allocation of attention has more degrees of freedom. For example, when participants are asked to perform discrimination based on some facial attributes (e.g., expression, gender, gaze direction etc.) the participants have to pay attention to faces independent of whether they are presented live or as pictures. Instead, it is possible that participants allocate considerably less attention to faces without than with a face-related task and, moreover, that there is also a discrepancy in attention allocation between live faces and pictures of faces. A live face is potentially capable for changes (e.g., expression, gaze direction, mouth area movements) and the changes are likely to be somewhat intentional. A live face is "present", whereas the face pictures lack the charm of immediate presence. Moreover, there may be greater spontaneous attention to the eyes presented live vs. as pictures due to social learning: when facing another person for the first time, at least in western cultures it is common to catch the eyes of the other when initiating social interaction (Argyle, 1981). Hence, as suggested also in our previous studies (Hietanen et al., 2008; Pönkänen et al., in press), free viewing of face pictures is likely to be less motivating and less attention-demanding than free viewing of live faces. Therefore, in the present study, we continued investigating the effects of seeing another person's direct vs. averted gaze on functioning of the approach–avoidance brain systems (frontal EEG asymmetry and autonomic responses) by comparing the effects of gaze direction between live vs. picture presentation modes, but this time in a condition where the participants were performing face-related tasks

during the stimulus presentation. In the present study, we used two “online” tasks: discrimination of another’s gaze direction and evaluation of one’s own feelings of pleasantness in response to this stimulus. By including these two tasks we aimed at explicit simulation of other- and self-related mental attributions which are suggested to interplay in social cognitive processing (Legrand & Ruby, 2009; Mitchell, 2009).

In our previous study (Hietanen et al., 2008), we suggested that the differential physiological responses between live and picture conditions could be related to differences in experienced self-awareness when facing a live person vs. a picture, i.e., differences due to the fact that, in the live condition, the perceiver knows that the other person can really see him/her, whereas in the picture condition the perceiver knows that this is not the case. In the present study, we were interested in expanding our previous results by investigating whether the *gaze direction* can modulate the self-awareness evaluations. In Hietanen et al. (2008) study, we compared self-awareness ratings during viewing of live vs. picture faces with a direct gaze. The results showed that subjective ratings of “public self-awareness”, related to the feelings of how one is perceived in the eyes of others (Govern & Marsch, 2001), were higher when the faces were presented live vs. as pictures. Interestingly, evaluations of the other two types of self-awareness, directed to one’s inner feelings or relations to external surroundings, were not affected by the presence of a live vs. picture face. In the present study, we wanted to investigate whether public self-awareness ratings are also influenced by the gaze direction, and whether the possible influence is restricted only to live faces.

In sum, in the present study, we measured relative hemispheric asymmetry in the frontal EEG and skin conductance responses (SCRs) to another person’s direct and averted gaze presented live through an LC window vs. as pictures on a computer screen. During physiological recordings, the participants were performing two tasks: gaze direction discrimination and evaluation of one’s own feelings of pleasantness towards the stimulus

face. We also studied whether the gaze direction has an effect on the subjective ratings of self-awareness and, especially, on self-awareness related to how one is perceived in the eyes of the other people. This was investigated by employing the Situational Self-Awareness Scale questionnaire (SSAS; Govern & Marsch, 2001). Finally, we also wanted to investigate if the sex of the stimulus face would modulate the results. In our previous study (Hietanen et al., 2008), participants were shown only female faces. However, females have been reported being more approachable than males when rating facial pictures (Campbell et al., 2010). It is thus possible that the motivation- and affect-related psychophysiological responses could be sensitive to the sex of the gazing person. In the present study, therefore, we decided to use both a female and a male model as stimuli. Because this was the first study in which we attempted to investigate the possible effects of stimulus face sex on neural approach-avoidance -related responses, we recruited female participants only. Previous research has shown that females show greater physiological responses to emotion-related facial cues than males (e.g., Anokhin & Golosheykin, 2010), and females are behaviourally more sensitive to eye gaze as compared to males (Gueguen & Jacob, 2002). Four main hypotheses were tested: i) perceiving a direct gaze would elicit relative left-sided frontal EEG asymmetry indicative of a motivational tendency to approach and averted gaze would elicit smaller relative left-sided asymmetry or even relative right-sided asymmetry indicative of avoidance, ii) the SCR would be greater for the direct vs. averted gaze, iii) public self-awareness would be heightened in response to a direct vs. averted gaze, and iv) to extend and corroborate the earlier findings (Hietanen et al., 2008), we expected to obtain all these effects in the live but not in the picture presentation mode also when we apply a concomitant behavioural task to ensure comparable attention allocation to faces in both stimulus presentation modes.

## 2. Materials and Methods

### 2.1 Participants

The participants were 25 right-handed female undergraduates (mean age = 21.3 years, range = 19–26 years) who gained course credits for participation. All participants had normal or corrected-to-normal vision. Informed, written consent was obtained from each participant prior to the experiment in accordance with the declaration of Helsinki. Two participants were removed from the final EEG analysis due to excessive artefacts. In addition, four participants were excluded from the final SCR analysis due to a technical error (N = 1), or excessive artefacts (N = 3). In one participant, collection of the SSAS data (see below) was not successful due to a technical error. Hence, the final data sample included 23 participants for the EEG, 21 participants for the SCR, and 24 participants for the SSAS. In the final EEG sample, 11 of the participants saw the female stimulus person and 12 of them saw the male stimulus person (see below). In the SCR sample, these figures were 11 (female stimulus) and 10 (male stimulus), and in the SSAS sample, 12 and 12, respectively.

### 2.2. Stimuli and Experimental Procedure

The stimuli were faces gazing either straight forward or gazing 30° to the left or to the right. The stimulus persons aimed at having a neutral expression on their face. The stimulus persons were the two experimenters collecting the data: a female (L.M.P.) and a male (M.J.P.), presented in Figure 1. The experimenter who was serving as a stimulus person did not give the instructions to the participant although she/he assisted in the preparation of the physiological recordings. The faces were presented in two conditions: live and picture. In the picture condition, a digital photograph of the model's face was presented on a computer screen. In the live condition, the faces were presented through a 30 x 40 cm LC shutter (LC-TEC Displays AB), attached to a white frame between the stimulus person and the participant. The LC-shutter switched between opaque and transparent states within an overall speed of 3



milliseconds. In both the picture and live condition, the participants were seated at a distance of 70 cm from the computer screen/panel, and in the live condition the model was sitting at a distance of 30 cm from the panel. The retinal size of the faces was similar in both conditions: approximately 8.0° horizontally and 11° vertically.

[Insert Figure 1 about here]

The stimuli were presented in two separate blocks: one for the live faces and the other for the pictures. The order of the presentation mode (live/picture) was counterbalanced across the participants. For each participant, the same person was presented as a live and a picture stimulus. Half of the participants saw the female model and the other half the male model. Within a block, there were a total of 16 trials. On 8 trials, the gaze was direct and, on the remaining 8 trials, the gaze was averted (left and right). The presentation order of the trials within a block was pseudo-random (no more than three consecutive trials of the same type). Each trial lasted for 5 seconds, and the inter-stimulus-interval (ISI) varied randomly from 25 to 30 seconds. This ISI range was employed due to the relatively long recovery period of the SCR. During the ISI, the shutter remained opaque and the computer screen had a black background. A short audio signal was presented through the speakers 5 seconds before the start of the next trial to direct the participant's attention to the shutter/computer screen and, in the live condition, to prepare the stimulus person to the opening of the shutter. Stimulus presentation was controlled in both presentation conditions by Neuroscan Stim software running on a desktop computer.

After arriving to the laboratory, the experimenter described the general procedure and explained that the participant's physiological responses would be measured while she viewed another person's face. The participants were instructed to remain relatively motionless during the trials and to respond verbally immediately after each trial whether the gaze direction of the stimulus face they saw was direct or averted. Immediately after each gaze discrimination

response, the participants were asked to consider how they felt during the stimulus presentation and slide a lever accordingly. The lever of the potentiometer moved approximately 4 cm forwards or backwards from the central position labelled as “neutral”. The end that was closer to the subject was labelled “pleasant” and the other end was labelled “unpleasant”. The participants were able to use the device with slight finger movements of their dominant hand. The output voltage of the potentiometer was registered with the same equipment that was used to measure SCR. During the experiment, one experimenter sat near the participant in such a way that he/she was invisible to the participant, but was able to observe and make record of the participant’s possible body movements and also, in the live face condition, the model’s possible movements, eye-blinks, and facial actions. These records verified that the models remained as motionless as possible, and they did not blink during the stimulus presentation. The experimenter also recorded the participant’s answers regarding the model’s gaze direction.

After the physiological recordings, there was a short pause. After the pause, the participants were introduced to the SSAS questionnaire (Govern & Marsch, 2001). Three of the 9 items of SSAS questionnaire measure public self-awareness (e.g., Right now, I am concerned about the way I present myself), three of the items measure private self-awareness (e.g., Right now, I am conscious of my inner feelings), and three of the items measure awareness of “immediate surroundings” (e.g., Right now, I am keenly aware of everything in my environment). The items have a seven-point scale from 1 (strongly disagree) to 7 (strongly agree). SSAS ratings were collected in two blocks: for live and picture faces. For the participants, the order of these blocks was the same as during physiological recordings. In each block, there were a total of six trials: three with direct gaze and three with averted gaze. The presentation of the items of the SSAS questionnaire was arranged in such a way that for both gaze directions, ratings to all 9 items were collected. The participants were instructed to

watch the stimulus and to complete a set of three questions after every trial. After answering to each set of questions, the participants were asked to inform the experimenter when they were ready to look at the next stimulus face (and to complete the next three questions). When the whole experiment was completed, the participants were debriefed and thanked for their contribution.

### *2.3. Acquisition of the Physiological Data*

Continuous EEG was recorded with tin electrodes mounted in a stretch lycra electrode cap (Electro-Cap International, Eaton, OH) from F3, F4, F7, F8, C3, Cz, C4, P3, and P4. The signal was also recorded from the left ear (A1), and referenced online to the right ear (A2). Horizontal (HEOG) and vertical (VEOG) eye movements were monitored bipolarly from the sites beside the outer canthi of each eye (HEOG) and above and below the left eye (VEOG). Skin abrasion and electrode paste were used to reduce the electrode impedances below 5 k $\Omega$ . The EEG signal was amplified with SynAmps amplifiers with a gain of 5000 and a 1-200 Hz band-pass filter (50-Hz notch filter enabled). The continuous signal was digitized at 1000 Hz and stored on a computer disk for off-line analyses. For the skin conductance measurements, the electrodes (Ag/AgCl) were coated with electrode paste and attached to the palmar surface on the medial phalanxes of the index and middle fingers on the participant's non-dominant hand. The signal was acquired with a SCR amplifier supplying constant-voltage AC excitation (22 mV) (ADInstruments). Power Lab 400 equipment was used to measure the skin conductance. Data collection was controlled by Power Lab Chart v3.6 computer programme running on a Power Macintosh 7100/80 computer. The skin conductance coupler was calibrated prior to each session to detect activity in the range of 0–40  $\mu$ Mho. The sampling rate was 100/s.

### *Data analysis*

Off-line, the continuous EEG signal was corrected for blink artifact using a regression-based blink reduction algorithm (Semlitsch et al., 1986), and referred to both ears. Eye movements other than blinks and other visible artifacts were eliminated on the basis of visual inspection. Artifact-free EEG during the 5-s stimulus period was segmented to eight 1.024-ms epochs with 75% overlap between adjacent epochs. Spectral power was calculated for each epoch using Fast Fourier Transform (FFT) with a 10% Hanning taper. The obtained power spectra were averaged over all artifact-free epochs within each trial and over separate trials within each experimental condition. Trials with less than 50% artifact-free epochs were excluded from averaging. Based on this criterion, 5 % of the trials were eliminated. For average power spectra within each condition, power density values ( $\mu V^2$ ) within the alpha band (8-13 Hz) were calculated and natural ln-transformed to normalize the distributions. Asymmetry scores were calculated for electrode pairs at frontal (F8/F7, F4/F3), central (C4/C3), and parietal (P4/P3) scalp regions by subtracting the ln-transformed power density values for the left site from that for the right site (Allen et al., 2004). Alpha activity has been shown to be inversely related to cortical activity (Davidson et al., 2000). The main data analysis was confined to the data measured from the electrode pair F4/F3. The affective and motivational effects on the frontal EEG asymmetry are frequently detected from these recording sites (Davidson, 1995). However, the other recording sites were also analyzed to detect the relative asymmetry differences. Analysis of the data from the other recording sites revealed that also in the present study the investigated effects were significant from the mid-frontal electrode pair F4/F3 only. The SCR was defined as a maximum change from the baseline level (at the stimulus onset) during a 4-second time period starting after 1 second from the stimulus onset till the end of the stimulus presentation. Responses contaminated by participant's body movements or technical problems during the measurement were eliminated from subsequent analysis. Based on these criteria, 19% of the trials were eliminated. A

Wilcoxon signed-ranks test indicated that the number of eliminated trials did not differ between direct and averted gaze neither in the live,  $Z = -.93$ ,  $p = .35$ , or picture,  $Z = -1.27$ ,  $p = .21$ , condition. For the statistical analyses, the data were averaged over the eight trials in each condition for each participant. The mean value of SCR was computed across all trials within the stimulus category including those without a measurable response as a zero response. This method of calculation results in the *magnitude* of the galvanic skin conductance responses (cf., Dawson et al., 1990). A log transformation [ $\log(\text{SCR}+1)$ ] was performed to normalize the data. The output voltages from the potentiometer used for pleasantness ratings were transformed to range between -2 (extremely unpleasant) and 2 (extremely pleasant).

### 3. Results

In the gaze discrimination task, the overall response accuracy was very high, 99.6 %. A Wilcoxon signed-ranks test showed that the accuracy did not differ between direct and averted gaze neither in the live,  $Z = -.45$ ,  $p = .66$ , or picture,  $Z = 0$ ,  $p = 1$ , condition. For the pleasantness ratings, a three-way ANOVA (with Gaze and Presentation Mode as within-subject factors and Stimulus Sex as a between-subject factor) showed a significant main effect of Presentation Mode,  $F(1,23) = 6.99$ ,  $p = .014$ ,  $\eta_p^2 = .23$ , indicating that, overall, the picture condition ( $M = 0.52$ ,  $SD = 0.61$ ) was evaluated as slightly more pleasant than the live condition ( $M = 0.32$ ,  $SD = 0.59$ ). The main effects of Gaze or Stimulus Sex were not significant,  $ps > .4$ . There were no significant interaction effects, all  $ps > .05$ , but the interaction between Presentation Mode and Stimulus Sex approached significance,  $F(1,23) = 3.40$ ,  $p = .078$ ,  $\eta_p^2 = .13$ . In the live condition, there was no difference in the ratings between the female and male model ( $M = 0.31$ ,  $SD = 0.59$  vs.  $M = 0.32$ ,  $SD = 0.62$ ). In the picture condition, the female model obtained higher ratings than the male model ( $M = 0.65$ ,  $SD = 0.53$  vs.  $M = 0.38$ ,  $SD = 0.66$ ), although this difference did not turn out to be statistically significant,  $p > .2$ .

A three-way ANOVA on the frontal EEG asymmetry scores indicated a Gaze  $\times$  Presentation Mode  $\times$  Stimulus Sex interaction,  $F(1,21) = 7.35$ ,  $p = .013$ ,  $\eta_p^2 = .26$ . As a consequence, the effect of gaze was analysed separately for both presentation modes and for female and male stimuli (Figure 2). For the live female stimulus, the mean asymmetry score was significantly higher (greater relative left-sided asymmetry) for the direct vs. averted gaze,  $t(10) = 3.42$ ,  $p = .007$ , whereas there was no difference in the asymmetry scores between direct and averted gaze in the female picture presentation mode,  $t < 1$ . For the male stimulus, the gaze direction did not have any effect on the asymmetry scores in the live or in the picture condition,  $t_s < 1$ . Moreover, in the live condition, the mean asymmetry score for the direct gaze was significantly higher for the female than the male stimulus person,  $t(21) = 3.11$ ,  $p = .005$ , whereas this was not the case in the picture presentation mode. There was no difference between the female and male stimuli in the asymmetry scores for the averted gaze in either presentation mode, both  $t_s < .1$ .

[Insert Figure 2 about here]

For the SCRs, a three-way ANOVA with Gaze and Presentation Mode as within-subject factors and Stimulus Sex as a between-subject factor showed no significant main effects. However, there was a Gaze  $\times$  Presentation mode interaction,  $F(1,19) = 6.24$ ,  $p = .022$ ,  $\eta_p^2 = .25$ . Stimulus Sex was not interacting with any of the other factors, all  $p_s > .05$ . As a result, the live and picture conditions were analysed separately. A paired samples  $t$ -test showed that, in the live condition, the SCR was larger for the direct vs. averted gaze,  $t(20) = 3.12$ ,  $p = .005$ . In the picture condition, there was no significant difference between direct and averted gaze,  $t < .1$ . Figure 3 shows the mean SCRs as a function of gaze direction and presentation mode.

[Insert Figure 3 about here]

The SSAS rating data were analyzed separately for each three subscales of self-awareness (public, private, and surroundings; see Table 1). Each subscale was analyzed with a three-way ANOVA, Gaze and Presentation Mode as within-subject factors and Stimulus Sex as a between-subject factor. For the public self-awareness, there was an interaction between gaze direction and presentation mode,  $F(1,22) = 5.79$ ,  $p = .025$ ,  $\eta_p^2 = .21$ , but no significant main effects or other interactions. In the live condition, the public self-awareness was marginally higher for direct ( $M = 3.38$ ,  $SD$ ) vs. averted gaze ( $M = 2.85$ ),  $t(23) = 1.92$ ,  $p = .067$ . In the picture condition, the gaze direction had no effect on public self-awareness,  $t < 1$ . The public self-awareness was higher also for the direct gaze in the live ( $M = 3.38$ ) than in the picture ( $M = 2.86$ ) presentation mode,  $t(23) = 2.59$ ,  $p = .016$ . Importantly, the other types of self-awareness ratings (private and surroundings) did not show any significant main effects or interactions in either presentation mode. For all three types of self-awareness ratings, the Stimulus Sex did not have any significant effects either.

[Insert Table 1 about here]

Finally, we investigated with a four-way ANOVA (with Gaze and Presentation Mode as within-subject factors and Stimulus Sex and Presentation Order as between-subject factors) whether the stimulus presentation order (the live faces presented before or after the face pictures) had any influence on the present physiological and behavioural results. The Presentation Order showed no main or interaction effects, all  $ps > .1$ .

#### 4. Discussion

The results of the present study showed that seeing another person's direct vs. averted gaze elicited differential affective and motivational physiological responses, and that these differences were observed only when the participants (all females) were viewing a live female stimulus face, but not when viewing a live male face or when the face stimuli were shown as pictures on a computer monitor. The results corroborate the findings of our previous study

(Hietanen et al., 2008) in that looking at a live face with a direct gaze resulted in greater relative left-sided frontal EEG asymmetry and heightened skin conductance responses as compared to a face with an averted gaze. Given that the frontal EEG asymmetry has been suggested to be related to the motivational approach-avoidance tendencies (Davidson, 2004; Harmon-Jones, 2003; Harmon-Jones et al., in press; Harmon-Jones et al., 2006; Van Honk & Schutter, 2006), we propose that our present results may reflect the observers' greater motivational approach tendency to seeing another person with a direct vs. averted gaze. In this study we showed that the observed differences in physiological responses between live and picture conditions remained also when the participants actively engaged themselves with the faces by performing concurrent face-related tasks. Our present SCR results showed that a direct gaze was more arousing than averted gaze, again, only when faced live. The sex of the stimulus face had no influence on the SCRs. Other studies employing live presentation of faces are in line with these findings by showing enhanced autonomic arousal to live direct vs. averted gaze as indexed by increased SCRs (Nichols & Champness, 1971), and elevated blood pressure (Williams & Kleinke, 1993). Our SCR results also corroborate our present EEG findings showing that the gaze direction effect was limited to the live presentation mode. These results are also compatible with previous studies showing enhanced autonomic responses to eye contact with a live partner vs. looking at a picture presentation of the same person (Bailey et al., 1981). The systems regulating basic affective and motivational responses have been suggested to be comprised of sets of neural networks regulating the *direction* of the responses, i.e., the motivational tendency to approach or avoid the source of stimulation, and the energy used for these responses, i.e., the *intensity* of the motivational tendency (Lang et al., 1990). Thus, our results show that another person's gaze direction has an effect on the functioning of the two neural systems involved in the regulation of



motivational tendencies. This effect, however, was limited to viewing female but not male faces in female participants.

It was a surprising result that the effect of gaze direction on the frontal EEG asymmetry was observed for the female stimulus person, but not for the male stimulus person. Moreover, the mean asymmetry score for the direct gaze presented live was higher (indicating relative left-sided asymmetry) for the female than the male stimulus person (for the male stimulus person, the mean asymmetry score was negative, indicating relative right-sided asymmetry), whereas there was no difference in the asymmetry scores for the live averted gaze between the female and male stimulus persons. We admit readily that we have no obvious explanation for these findings and, therefore, in the following, we can provide only some speculation upon this issue. There are previous results showing that, for females, eye contact with opposite-sex avatar faces is not as pleasant as eye contact with same-sex avatars (Schrammel et al., 2009). In negotiating situations, females have been found to cooperate better when in eye contact with another female than when not, but this preference was not observed when females negotiated with males (Swaab & Swaab, 2009). There are also perceived differences in power distribution between female-female and female-male dyads. In general, females have been shown to view male targets as more dominant than female targets in trait attribution tasks (see Feingold, 1998, for a meta-analysis). Interestingly, previous findings have indeed shown that the frontal EEG asymmetry is sensitive to power expectancies. In one study, participants primed with feelings of being high in power over another individual were observed to exhibit pronounced relative left-sided frontal asymmetry, whereas participants primed with low power expectancies showed relative right-sided frontal asymmetry (Boksem et al., in press). Thus, one possibility is that, for our female participants, perceiving the male stimulus model's direct gaze evoked experiences of lower power status and a shift towards a relative right-sided frontal asymmetry, and this, in turn, resulted in no difference in the asymmetry scores for the

male model's direct vs. averted gaze. Since we had only one female and one male as stimuli, another possibility is that some facial attributes in the stimulus persons, irrespective of their sex, evoked differential affective reactions. These, in turn, might have interacted with the motivational reactions to gaze direction.

In fact, we collected supplementary data by showing face photographs of both of our stimulus persons (the same photographs which were used in the picture condition) together with corresponding pictures from faces of four other individuals (2 males and 2 females) to 12 additional female participants. Like in the experiment, each picture was shown for 5 seconds. Immediately after each picture, the face was rated on a 7-point scale for the following characteristics: fear, joy, anger, sadness, surprise, disgust, approachability, dominance, and likeability. The results showed that the female model was evaluated as expressing less anger  $t(11) = -2.86, p = .015$ , and disgust,  $t(11) = -2.38, p = .036$ , but more sadness,  $t(11) = 2.24, p = .047$ , than the male model. In addition, the female model was evaluated as being more likeable than the male model,  $t(11) = 2.55, p = .027$ . The differences in other evaluation domains were not significant. The value of these additional data is limited as the raters did not participate in the original study and they looked at the face pictures only. Nevertheless, these results suggest that the faces of our two models indeed may have evoked differential evaluative responses. Except for sadness, the female model gained more favorable evaluations. Interestingly, although sadness can be regarded as a negative emotion, it has been shown to activate automatic approach motivation (Seidel et al., 2010). The gender role expectations might also have interacted with the impressions given by the stimulus faces: for instance, neutral expressions have been inferred to reflect dominance in men but not in women (Hareli et al., 2009).

It is apparent that the effects of both the participant's and the model's sex (as well as the effects of perceived facial affects) on gaze-related frontal asymmetry responses should be

addressed in future studies. Although re-analysis of the results from our previous study (Hietanen et al., 2008) showed no effects of participant's sex (12 females, 8 males) on the responses to direct vs. averted gaze of the female models, it is obvious that now, after finding a significant effect of the model's sex, this issue should be investigated by employing a fully factorial (participant's sex  $\times$  the model's sex) experimental design. In a recent study where the approachability of female and male faces were rated, the results showed that, although the female faces were rated overall as more approachable, both the female and male participants rated the own-sex faces more approachable than the opposite-sex faces (Campbell et al., 2010).

Even though the asymmetry scores were higher for the direct than averted gaze for the live female face, both gaze directions resulted in relative left-sided frontal asymmetry. In our previous study with female stimulus faces (Hietanen et al., 2008), however, averted gaze elicited relative right-sided asymmetry. These differences may relate to the processing strategy. In our previous experiment, the participants were viewing the faces freely, without a concomitant task, whereas in the present experiment they were actively engaged by the two tasks. The level of engagement during task-related processing has been shown to affect frontal alpha activity, particularly when the task has been related to rewards (Miller & Tomarken, 2001). It is possible that an active discrimination of gaze direction and especially the pleasantness evaluations rendered viewing of an averted gaze also a goal-directed process with high personal relevance. In the present study, however, the tasks were completed rather effortlessly. For instance, a recent study showed that face pictures having a direct gaze elicited greater arousal than those with an averted gaze (or closed eyes) when presented in the context of a demanding word-spelling task, but the effect was not observed in the context of a similar but easier task (Conty et al., 2010a). In their study, however, the tasks were not related

to the face stimuli, as was the case in the present study. It would be warranted to study the effects of the task type and difficulty also with faces presented live.

In the present study, direct gaze elicited higher ratings of public self-awareness in the live than in the picture condition, replicating the finding by Hietanen et al. (2008). Moreover, we expanded these previous findings by showing that, in the live condition only, the other person's gaze direction had an influence on the self-rated public self-awareness: direct gaze evoked marginally higher ratings as compared to averted gaze. This type of awareness possibly makes the person alert and sensitive to others' motivational signals, whether being positively tuned or not. In concordance with our earlier studies comparing live vs. picture presentation of faces (Hietanen et al., 2008; Pönkänen et al., in press), we suggest that being looked at, or not, by a real person activates self-directed reflective processes differently than when looking at a picture of another person's face. Self-awareness, especially the "public" type of it, may relate to the feeling of being observed by another person. A picture cannot observe the intentions of the perceiver, but a sentient other can. In the present study, mental state attribution was more relevant in the live than in the picture condition. In live condition only the observed direct gaze had an actual, known target: the participant.

More recently, others have shown that knowledge of the other person's capability to see the observer can influence social-cognitive processes. Attention direction adaptation (Teufel et al., 2009) and automatic attention shifts by head orientation cues (Teufel et al., 2010a) has shown to be modulated depending on whether the participants were lead to believe that the other person was capable of seeing them or not via a video-link. Compatible with our previous propositions (Hietanen et al., 2008; Pönkänen et al., 2008), Teufel et al. (2010b) proposed that mental-state attributions could modulate even the basic perceptual processing of social stimuli. Thus, the lack of the measured affective and motivational physiological responses to face pictures in the present as well as in our previous study (Hietanen et al.,

2008) may reflect the effects of mental-state attributions already at the early stage perceptual processing. This possibility is, in fact, supported by our previous results showing that the early, face sensitive N170 ERP response discriminated between direct and averted gaze in the live, but not in the picture condition (Pönkänen et al., in press). However, it is also possible that the effects of mental-state attributions on social cognitive processes are augmented as one proceeds from basic perceptual processes to more complex socio-behavioral responses, to motivational responses and to preparation of overt actions. This possibility is supported by findings from studies investigating mentalizing-related brain activity to non-human vs. human actors. Although implying agency to non-human actors in computer-mediated games is capable of activating brain areas related to mentalizing, the activation has been shown to be greater in response to human game partners (Kircher et al., 2009; Rilling et al., 2004). Apparently, more studies are needed to clarify the role of mental-state attribution and self-awareness in affective and motivational processing of non-responsive vs. responsive faces. We suggest that behind all successful social engagement is the feeling of being together, being regarded as a mindful creature by another mindful creature. Whether it functions regardless of the media that aims at connecting people warrants further studying.

The behavioural results of the present study showed that the gaze direction did not have an effect on pleasantness ratings. Regardless of gaze direction, however, viewing the pictures was rated as more pleasant than viewing the live faces. It is possible that looking at and evaluating a silent, live face behind the LC window for an unusually long time (5 seconds) elicited feelings of being under the other person's control, and this resulted in slightly lower pleasantness ratings compared to observing pictures of faces. The participants did not know the purpose of the study, but they presumably thought that the stimulus person facing them knew better, the fact that we had the experimenters of this study as stimulus persons even reinforcing this notion. The lack of control over the interaction process likely

relates to the inability to affect the other person's behaviour (for instance, if the participant smiles, the stimulus person does not smile back), which might have caused feelings of powerlessness, and even exclusion. Thus, the lower overall ratings of pleasantness in the live vs. picture condition might have reflected perceived differences in the control of the situation between the participant herself and the stimulus person in the live condition. This possibility should be investigated in further studies controlling for the power differences.

In order to be successful, social interaction requires both ongoing evaluation of the social signals sent by the interaction partner and monitoring of one's own feelings and thoughts. In social neuroscience and related fields, there has been discussion on the growing need to define the "social" in social perception and interaction more precisely (De Jaegher, 2009; Kingstone et al., 2008; Teufel et al., 2010; Zaki & Ochsner, 2009) and to take into account the complexities of real-world situations (Kingstone et al., 2008). For instance, one might ask whether the social processes are similar when investigating reciprocal, face-to-face engagement in a computer-mediated context (i.e., Wilms et al., 2010) as opposed to situations when two persons are mutually present, situated physically close to each other. Recent theoretical viewpoints have highlighted the self as an enactive being; perception and movement are closely intertwined, and people are continuously aware of their bodies in relation to external objects (McGann & De Jaegher, 2009; Zahavi, 2002). For visual perception, this can be especially meaningful with other people being those objects in sight. It is possible that live interaction with others sharing the same space makes us more aware of the mobility and spatial representation of our own body, in order to react adaptively to others' bodily responses in our vicinity. Zahavi (2002) refers to Edmund Husserl's phenomenological views in stating that "hand cannot touch without being touched". Similarly, perhaps, the gaze cannot meet without being met.

#### Acknowledgements

This research was supported by the Academy of Finland (project n:o #130272 to J.K.H.), the Finnish Graduate School of Psychology, and the Emil Aaltonen Foundation.

## References

- Allen, J. J. B., Coan, J. A., & Nazarian, M., 2004. Issues and assumptions on the road from raw signals to metrics of frontal EEG asymmetry in emotion. *Biol. Psychol.* 67, 183-218.
- Andreassi, J. L., 2000. *Psychophysiology: Human behavior & physiological response*, 4th edn., Lawrence Erlbaum Associate, New Jersey.
- Anokhin A. P., & Golosheykin S., 2010. Startle modulation by affective faces. *Biol. Psychol.* 83, 37-40.
- Argyle, M., 1981. *Bodily Communication*. Methuen, London.
- Bailey, R. C., Chorosevic, P., White, D., & White, H., 1981. Physiological arousal and perceptions of a member of the opposite sex. *J. Soc. Psychol.* 115, 271-276.
- Boksem, M. A. S., Smolders, R., & De Cremer, D., in press. Social power and approach-related neural activity. *Soc. Cogn. Affect. Neurosci.* doi:10.1093/scan/nsp006.
- Campbell, D. W., Neuert, D., Friesen, K. B., McKeen, N. A., 2010. Assessing Social Approachability: Individual Differences, In-Group Biases, and Experimental Control. *Can. J. Behav. Sci.* 42, 254-263.
- Conty, L., N'Diaye, K., Tijus, C., & George, N., 2007. When eye creates the contact! ERP evidence for early dissociation between direct and averted gaze motion processing. *Neuropsychologia* 45, 3024-3037.
- Conty, L., Russo, M, Loehr V, Hugueville L, Barbu S, Huguet P, Tijus C, George N., 2010. The mere perception of eye contact increases arousal during a word-spelling task. *Soc. Neurosci.* 5, 171-186.
- Davidson, R. J., 1995., Cerebral asymmetry, emotion, and affective style. In Davidson, R. J., & Hugdahl, K. (Eds.), *Brain Asymmetry*, MIT Press, Cambridge, MA, pp. 361-387.



- Davidson, R. J., 2004. What does the prefrontal cortex “do” in affect: perspectives on frontal EEG asymmetry research. *Biol. Psychol.* 67, 219-233.
- Davidson, R. J., Jackson, D. C., & Larson, C. L. 2000. Human electroencephalography. In Cacioppo, T. J., Tassinary, L. G., & Bernston, G. G. (Eds.), *Handbook of Psychophysiology*, Cambridge University Press, New York, pp. 27-52.
- Dawson M., Schell A., Fillon D., 1990. The electrodermal system. In: Cacioppo J. T., Tassinary L. G. (Eds.), *Principles of psychophysiology*, Cambridge University Press, New York, pp. 295-324.
- De Jaegher, H., 2009. Social understanding through direct perception? Yes, by interacting. *Conscious. Cogn.* 18, 535-542.
- Exline, R., Gray, D., & Schuette, D., 1965. Visual behavior in a dyad as affected by interview content and sex of respondent. *J. Pers. Soc. Psychol.* 1, 201-209.
- Feingold, A., 1998. Gender stereotyping for sociability, dominance, character, and mental health: a meta-analysis of findings from the bogus stranger paradigm. *Genetic, Social & General Psychology Monographs* 124, 253-270.
- McGann, M., & De Jaegher, H., 2009. Self-other contingencies: enacting social perception. *Phenomenology and Cognitive Sciences* 8, 417-437.
- George, N., & Conty, L., 2008. Facing the gaze of others. *Clin. Neurophysiol.* 38, 197-207.
- Govern, J. M., & Marsch, L. A., 2001. Development and validation of the situational self-awareness scale. *Conscious. Cogn.* 10, 366-378.
- Gueguen, N., & Jacob, C., 2002. Direct look versus evasive glance and compliance with request. *J. Soc. Psychol.* 142, 393-396.
- Hareli, S., Shomrat, M., & Hess, U., 2009. Emotional versus neutral expressions and perceptions of social dominance and submissiveness. *Emotion*, 9, 378-384.

- Harmon-Jones, E., 2003. Clarifying the emotive functions of asymmetrical frontal cortical activity. *Psychophysiology* 40, 838–848.
- Harmon-Jones, E., Gable, P. A., & Peterson, C. K., in press. The role of asymmetric frontal cortical activity in emotion-related phenomena: a review and update. *Biol. Psychol.* 2009, doi: 10.1016/j.biopsycho.2009.08.010.
- Harmon-Jones, E., Lueck, L., Fearn, M., & Harmon-Jones, C., 2006. The effect of personal relevance and approach-related action expectation on relative left frontal cortical activity, *Psychol. Sci.* 17, 434-440.
- Hietanen, J. K., Leppänen, J. M., Peltola, M. J., Linna-aho, K., & Ruuhiala, H. J., 2008. Seeing direct and averted gaze activates the approach-avoidance motivational brain systems. *Neuropsychologia* 46, 2423-2430.
- Kingstone, A., Smilek, D., & Eastwood, J. D., 2008. Cognitive Ethology: A new approach for studying human cognition. *Br. J. Psychol.* 99, 317-340.
- Kircher, T., Blumel, I., Marjoram, D., Lataster, T., Krabbendam, L., Weber, J. et al., 2009. Online mentalising investigated with functional MRI. *Neurosci. Lett.* 454, 176-181.
- Klinke, C. L., 1986. Gaze and eye contact: A research review. *Psychol. Bull.* 100, 78-100.
- Lang, P. J., Bradley, M. M., & Cuthbert, B. N., 1990. Emotion, attention, and the startle reflex. *Psychol. Rev.* 97, 377-395.
- Legrand, D., & Ruby, P., 2009. What is self-specific? Theoretical investigation and critical review of neuroimaging results. *Psychol. Rev.* 166, 252-282.
- Mason, M. F., Tatkov, E. P., & Macrae, C. N., 2005. The look of love: Gaze shifts and person perception. *Psychol. Sci.* 16, 236-239.
- Miller, A., & Tomarken, A. J., 2001. Task-dependent changes in frontal brain asymmetry: effects of incentive cues, outcome expectancies, and motor responses. *Psychophysiology* 38, 500-511.

- Mitchell, J. P., 2009. Social psychology as a natural kind. *Trends Cogn. Sci.* 13, 246-251.
- Nichols, K. A., & Champness B. G., 1971. Eye-gaze and the GSR. *J. Exp. Soc. Psychol.* 7, 623-626.
- Nummenmaa, L., Hyönä, J., & Hietanen, J. K., 2009. I'll walk this way: Eyes reveal the direction of locomotion and mark passersby look and go the other way. *Psychol. Sci.* 20, 1454-1458.
- Pönkänen, L. M., Alhoniemi, A., Leppänen, J. M., & Hietanen, J. K., in press. Does it make a difference if I have an eye contact with you or with your picture? An ERP study. *Soc. Cogn. Affect. Neurosci.* doi: 10.1093/scan/nsq068.
- Pönkänen, L. M., Hietanen, J. K., Peltola, M. J., Kauppinen, P. K., Haapalainen, A. & Leppänen, J. M., 2008. Facing a real person: an event-related potential study. *Neuroreport* 19, 497-501.
- Rilling, J. K., Sanfey, A. G., Aronson, J. A., Nystrom, L. E., & Cohen, J. C., 2004. The neural correlates of theory of mind within interpersonal interactions. *Neuroimage* 22, 1694-1703.
- Sato, W., Kochiyama, T., Uono, S., Yoshikawa, S., 2008. Time course of superior temporal sulcus activity in response to eye gaze: a combined fMRI and MEG study. *Soc. Cogn. Affect. Neurosci.* 3, 224-232.
- Schilbach, L. Wohlschlaeger, A. M., Kraemer, N. C., Newen, A., Shah, N. J., Fink, G. R., et al., 2006. Being with virtual others: neural correlates of social interaction. *Neuropsychologia* 44, 718-730.
- Schrammel, F., Pannasch, S., Graupner, S-T., Mojzisch, A., & Velichovsky, B., 2009. Virtual friend or threat? The effects of facial expression and gaze interaction on psychophysiological responses and emotional experience. *Psychophysiology* 46, 922-931.

- Seidel, E.-M., Habel, U., Kirschner, M., Gur, R. C., Derntl, B., 2010. The impact of facial emotional expressions on behavioral tendencies in women and men. *J. Exp. Psychol. Hum. Percept. Perform.* 36, 500-507.
- Semlitsch, H. V., Anderer, P., Schuster, P., & Presslich, O. A., 1986. Solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology* 23, 695-703.
- Swaab, R. I., & Swaab, D. F., 2009. Sex differences in the effects of visual contact and eye contact in negotiations. *J. Exp. Soc. Psychol.* 45, 129-136.
- Teufel, C., Alexis, D. M., Todd, H., Lawrence-Owen, A. J., Calyton, N. S., & Davis, G., 2009. Social cognition modulates the sensory coding of observed gaze direction. *Curr. Biol.* 19, 1274-1277.
- Teufel, C., Alexis, D. M., Todd, H., Calyton, N. S., & Davis, G., 2010a. Mental state attribution drives rapid, reflexive gaze following. *Atten. Percept. Psychophys.* 72, 695-705.
- Teufel, C., Fletcher, P. C., & Davis, G., 2010b. Seeing other minds: attributed mental states influence perception. *Trends Cogn. Sci.* 14, 376-382.
- Van Honk, J., & Schutter, D. J. L. G., 2006. From affective valence to motivational direction: the frontal asymmetry of emotion revised. *Psychol. Sci.* 17, 963-965.
- Williams, G. P., & Kleinke, C. L., 1993. Effects of mutual gaze and touch on attraction, mood, and cardiovascular reactivity. *J. Res. Pers.* 27, 170-183.
- Wilms, M., Schilbach, L., Pfeiffer, U., Bente, G., Fink, G. R., & Vogeley, K., 2010. It's in your eyes – using gaze-contingent stimuli to create truly interactive paradigms for social cognitive and affective neuroscience. *Soc. Cogn. Affect. Neurosci.* 5, 98-107.

- Weisbuch, M., Ivcevic, Z., & Ambady, N., 2009. On being liked on the web and in the “real world”: consistency in first impressions across personal webpages and spontaneous behavior. *J. Exp. Soc. Psychol.* 45, 573-576.
- Zahavi, D., 2002. First-person thoughts and embodied self-awareness: some reflections on the relation between recent analytical philosophy and phenomenology. *Phenomenology and the Cognitive Sciences* 1, 7-26.
- Zaki, J., & Ochsner, K., 2009. The need for a cognitive neuroscience of naturalistic social cognition. *Ann. N. Y. Acad. Sci.* 1167, 16-30.

Table 1

*Self-rated SSAS scores for three types of self-awareness (public, private, surroundings; scale range 1-7) as a function of stimulus type (eyes: direct, averted) and presentation mode.*

Presentation mode	Public		Private		Surroundings	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
<u>Live</u>						
Direct	3.38	1.26	3.36	1.03	3.46	1.32
Averted	2.85	1.22	3.38	1.18	3.68	1.18
<u>Picture</u>						
Direct	2.86	1.26	3.31	0.97	4.00	0.99
Averted	2.93	1.14	3.31	1.13	3.90	1.20

## Figure Captions

*Figure 1.* The faces of the female (above) and the male (below) stimulus models with direct and averted gaze.

*Figure 2.* Mean EEG frontal asymmetry scores for faces of the female (above) and male (below) stimulus models as a function of gaze direction and presentation mode. The ordinates express the difference in the EEG alpha power (in ln-transformed  $\mu\text{V}^2/\text{Hz}$ ) between electrodes F4 – F3. Positive values indicate relative left-sided asymmetry and negative values indicate relative right-sided asymmetry. The small insert graphs show the absolute values of the EEG alpha power recorded from the left hemisphere (L, electrode F3) and right hemisphere (R, electrode F4) electrodes in different stimulus conditions.

*Figure 3.* Mean skin conductance responses [in log-transformed (SCR+1)  $\mu\text{Mho}$ ] for faces as a function of gaze direction and presentation mode.

Figure 1





Figure 2

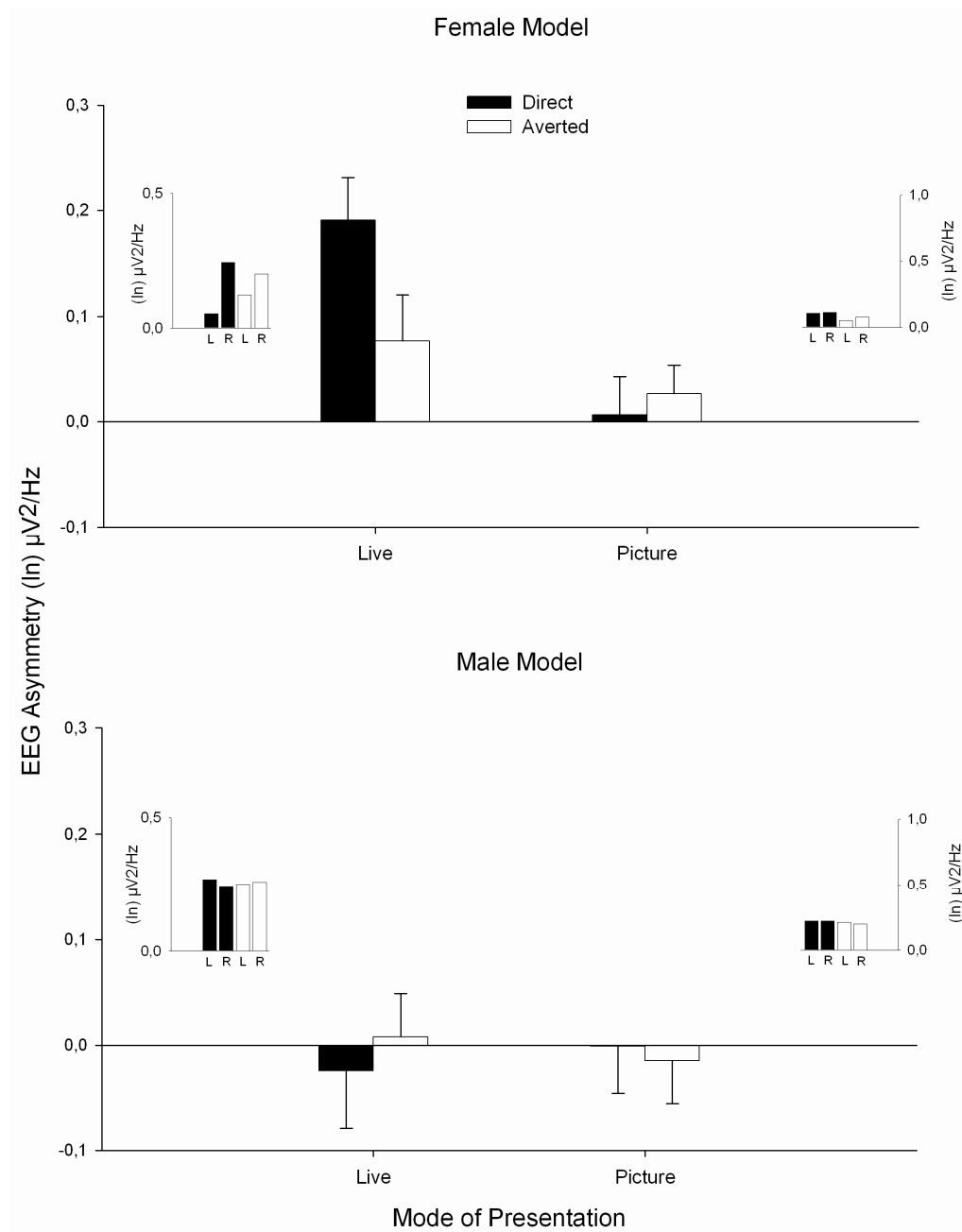


Figure 3

