INTRODUCTION

When two people happen to make eye contact, especially if not acquainted, they probably promptly start thinking whether the other person wants something from them, and how they look in the eyes of that person. It has been suggested that looking at the eyes of another person elicits a host of social cognitive and affective processes, such as heightened self-awareness and sense of intimacy (Argyle, 1981; Kleinke, 1986). In a live face-to-face situation, it is essential for a viewer to imagine him/herself in the eyes of the other, whose reactions may have a profound impact on the immediate interaction outcomes. However, looking at the eyes of a picture, for example, in networking communities, is not self-relevant in an immediate sense. A face picture, although capable of eliciting a variety of processes related to the mental state, cannot affect the perceiver physically. Another difference between seeing others’ faces live vs in a virtual/pictorial form relates to perspective taking. When faced with a picture or a virtual equivalent of another person, the viewer does not need to evaluate the impressions given to these characters as much as when faced with another person live. Hitherto, however, in face processing studies, face stimuli have usually been presented as pictures or animations on a computer screen. In the present study, we investigate the impact of direct gaze on the brain responses to another person’s face depending on whether the face is seen live or as a picture.

Several studies in the field of cognitive neuroscience have shown that face processing is specialized in adult human brain and that a large, distributed network of areas is involved in the processing of facial information (see Haxby et al., 2000 for a review). A feasible tool for studying the neurocognitive bases of face processing has been to measure event-related changes in electroencephalography (EEG) and magnetoencephalography (MEG) (i.e. Rossion and Jacques, 2008). Studies using these methods have shown that a negative occipitotemporal component N170 and its magnetic counterpart M170, peaking at 140–170 ms after stimulus presentation, is more sensitive to faces and isolated eyes than to other objects (Bentin et al., 1996; Sams et al., 1997; Itier and Taylor, 2004). The N170 is likely to reflect ‘the concept of a face’ (structural encoding of holistic face configuration). Realistic and schematic pictures of faces elicit generally the same pattern of N170 responses (Sagiv and Bentin, 2001), but, to the best of our knowledge, there is only one published study reporting N170 responses to facial stimuli other than pictures (Pölkänen et al., 2008). Recently, we examined the effect of presentation mode on ERP responses to faces by presenting human faces and realistic dummy faces as pictures on a computer screen and live through a computer-controlled liquid crystal (LC) shutter (Pölkänen et al., 2008). The study demonstrated that the N170 responses to a human face and a dummy face were indistinguishable in both viewing conditions. Instead, the human face elicited stronger middle-latency early posterior
negativity (EPN) than the dummy, but only when presented live. In the picture condition no such difference was observed. The EPN is a negative-going occipitotemporal potential occurring ~150–350 ms after stimulus onset and it has been associated with the perceptual encoding and early selection of visual stimuli carrying affective and motivational significance (Junghöfer et al., 2001; Schupp et al., 2007; Kissler et al., 2009). EPN has also been shown to be sensitive to faces classified as attractive (Werheid et al., 2007) and threatening (Schupp et al., 2004). We suggested that as a live human face has potential for social interaction, it is a motivationally significant stimulus and capable of eliciting greater EPN than a dummy face. Other recent results have also shown differential brain responses to live faces vs pictures. In a frontal EEG-asymmetry study (Hietanen et al., 2008), seeing another person with a direct gaze elicited a left-sided asymmetry associated with a motivational tendency to approach, whereas seeing an averted gaze elicited a right-sided asymmetry indicative of a motivational tendency of avoidance. Again, this pattern of results was observed only when the stimulus faces were seen live.

In the present study, we continued investigating whether the potentiality for interaction is reflected in the face-sensitive ERPs. Here, we examined the effects of gaze direction. Direction of gaze conveys valuable information about other peoples’ focus of interest. A direct gaze informs the observer that another person is looking at him or her and is probably willing to interact. Depending on the context, direct gaze can be seen as a sign of attraction (Mason et al., 2005), social control or threat (Kleinke, 1986; Emery, 2000). An averted gaze, in turn, signals diversion of interest towards targets in the nearby environment.

The eye region attracts attention from early on in human development, and it has been reported that typically developing infants (Taylor et al., 2001a; Farroni et al., 2002, 2004) and children (Senju et al., 2005) show greater ERPs to pictures of faces with a direct compared to averted gaze, reflecting enhanced perceptual processing of these faces. The gaze sensitive ERP results are less consistent in adults. Taylor et al. (2001b) reported no ERP differences between pictures of faces with direct and averted gaze. Instead, Watanabe et al. (2002) reported greater N170 for static faces with averted vs direct gaze, although only to a gaze averted to right. Similarly, in a combined MEG and fMRI study, responses around 170 ms after stimulus onset were more negative to averted vs direct gaze (Sato et al., 2008). Itier et al. (2007) showed greater N170 to an averted vs direct gaze with front-view faces only. Puce et al. (2000) also reported greater N170 when the eyes moved from direct to averted position compared to opposite gaze shifts. In contrast to these studies, Conty et al. (2007) reported larger ERPs to direct vs averted gaze. They showed that N170 was greater to eyes moving from an intermediate gaze direction to a direct position than to the opposite movement. The authors suggested that because they used a common baseline for both gaze directions, i.e. the intermediate eye position, the design was more appropriate for comparisons between direct and averted gaze. The greater amplitudes for the direct gaze were suggested to reflect an intensified early processing of direct gaze. They also showed that direct gaze resulted in increased P3 amplitudes, which presumably reflected stronger attention capture and intensified emotional processing.

In the present study, we investigated whether a model’s direct gaze enhances ERP responses to faces and whether this enhancement depends on the mode of stimulus presentation. Thus, we measured ERPs to faces with a direct gaze, averted gaze and closed eyes in two modes of presentation: live and picture. Although great care was taken to ensure that the stimuli were visually as similar as possible in both presentation modes, we cannot rule out certain low-level visual differences between the presentation modes. These include differences in the luminance and texture properties of the stimuli as well as possible minor facial movements in the live condition. Importantly also, live faces were 2D whereas pictures were 3D. Therefore, in our data analysis, we took a conservative approach and refrained from comparisons between the presentation conditions. To make the design more robust, we also included two ‘non-direct-gaze’ conditions. Eyes averted and eyes closed conditions are likely to evoke lower self-involvement and potentiality for interaction than the direct gaze condition. Moreover, like direct gaze, the eyes closed condition is visually symmetrical, offering a condition to control for a possible confounding effect of visual symmetry vs asymmetry in the eye region between faces with a direct vs an averted gaze. The participants also evaluated their affective responses during the ERP measurements. This was done to investigate whether the gaze direction had an influence on self-reported valence and arousal and whether they differed between presentation modes. In our earlier studies, both type of face (real vs dummy; Pönnänen et al., 2008), and gaze direction (Hietanen et al., 2008) affected the valence and arousal ratings only in the live condition. The main hypotheses were that i) the direct gaze would elicit more negative-going N170 and EPN amplitudes than both averted gaze and closed eyes and ii) these effects would be seen in the live condition only.

**METHODS**

**Participants**

The participants were 20 university undergraduates (16 females, right handed, mean age = 24.1 years, range 20–43) who gained a course credit for participation. All participants had normal or corrected-to-normal vision. Informed, written consent was obtained from each participant prior to the experiment.

**Stimuli and procedure**

The stimuli were static faces of an adult female displaying a neutral emotion and gazing either straight forward (direct), gazing 30° to the left or to the right (averted), or having the
eyes closed (closed). All stimuli were presented in two conditions: picture and live. In the picture condition, a digital photograph of the same person as in the live condition was presented on a computer screen. The participants were seated 70 cm away from the computer screen. The faces extended ~7.7° vertically and 5.3° horizontally. In the live condition, the stimuli were presented through a 40 × 3 cm voltage-sensitive LC shutter (LC-TEC Displays AB, Borlänge, Sweden) attached to a white frame between the stimulus person and the participant (Figure 1). The LC shutter switched between opaque and transparent states within an overall speed of 3 ms. The participants were seated at a distance of 110 cm from the frame and the model was seated at a distance of 53 cm from the frame. The retinal size of the faces was similar to that in the picture condition.

After the participants arrived to the laboratory the general EEG procedures were explained. The participants were told that the experiment concerned face processing and they were instructed to look at the stimulus faces as naturally as possible, and to remain relatively motionless during the trials. The live and picture stimuli were presented in separate blocks. In both blocks, 180 trials were presented (60 per stimulus type) with a 500-ms presentation time and a 2000-ms inter-stimulus interval. Within the blocks, the stimuli were presented in 10-trial sequences repeating the same stimulus. Within each block, there were six 10-trial sequences of direct, averted and closed eyes conditions. The order of these sequences was randomized. After each 10-trial sequence, there was a 15-s break. A short signal was given through the speakers 5 s before the start of the next 10-trial sequence to alert the participant, and, in the live condition, also the model behind the shutter. The presentation order of the stimulus blocks (picture vs live) was counterbalanced across participants. Immediately after each 10-trial sequence, the participants completed a paper-and-pencil Self-Assessment Manikin (Bradley and Lang, 1994) to assess their affective responses to the stimuli. Stimulus presentation was controlled in both conditions by NeuroScan Stim2 software running on a desktop computer.

Electrophysiological recordings and data analysis
Continuous EEG was recorded using an electrode cap (Electro-Cap) with 22 tin electrodes positioned according to the 10–20 system, and referenced to the nose tip. Horizontal (HEOG) and vertical (VEOG) eye movements were bipolarly monitored from the sites beside the outer canthi of each eye (HEOG) and above and below the left eye (VEOG). Skin was abraded to reduce the electrode impedances below 5 kΩ. The electrical signal was amplified with a 0.1–100 Hz band-pass filter (Neuroscan/SynAmps), digitized at 500 Hz, and stored on a computer disk.

Off-line, the continuous EEG signal was digitally filtered using a 30 Hz low-pass filter, and segmented to 600 ms epochs starting 100 ms prior to stimulus presentation. The segments were baseline-corrected against the mean voltage during the 100 ms pre-stimulus period. Segments with eye movements and blinks were excluded from further analyses using ±75 µV thresholds for the HEOG and VEOG. Average waveforms for each participant within each of the six experimental conditions were calculated from the accepted trials.

For N170, mean response amplitude was analysed within a 110–150 time window in the picture condition and within a 125–165 in the live condition, since N170 occurred later in the live condition. For EPN, the mean response amplitude was analyzed within a 190–290 ms time window in both conditions. Since the peak of N170 was not clear in all participants, the analysis of the peak latencies was not reasonable. The amplitude analyses were based on ERPs recorded from electrodes O1, O2, T5 and T6. In all cases, the analysis was a 3 (stimulus: direct gaze, averted gaze, eyes closed) × 2 (channel: temporal, occipital) × 2 (hemisphere: left, right) repeated measures analysis of variance (ANOVA). A Greenhouse-Geisser correction procedure was applied when necessary.

RESULTS
N170 amplitudes
The grand-averaged ERPs are illustrated in Figure 2. In the picture condition, a three-way ANOVA indicated a main effect of channel, $F(1,19) = 11.27$, mean square error ($MSE = 34.37$, $P < 0.01$, reflecting that the N170 amplitudes were more negative for temporal than for occipital channels, and a main effect of hemisphere, $F(1,19) = 11.52$, $MSE = 16.41$, $P < 0.01$, reflecting more negative N170 responses in the right than in the left hemisphere. None of the other effects were significant. In the live condition, there were main effects of channel, $F(1,19) = 27.31$, $MSE = 45.68$, $P < 0.001$, and hemisphere, $F(1,19) = 11.72$, $MSE = 12.11$, $P < 0.001$, reflecting more negative N170 responses in the right than in the left hemisphere.
Fig. 2 Grand-averaged ERP waveforms at the temporal T5 and T6 and occipital O1 and O2 channels for the three stimulus types (direct gaze, averted gaze and closed eyes) in the picture and live conditions.
of gaze, $P < 0.01$, reflecting more negative N170 amplitudes for temporal than occipital channels, and more negative responses in the right than left hemisphere. There was also a main effect of gaze, $F(2,38) = 3.92$, $MSE = 6.30$, $P < 0.05$, but no interaction effects. Pairwise comparisons (LSD) indicated that, for direct gaze ($M = 3.47 \mu V$), the N170 was shifted in the negative direction compared to responses for averted gaze ($M = 4.57 \mu V$), $P < 0.05$. The differences between direct gaze and closed eyes ($M = 4.18 \mu V$) and between averted gaze and closed eyes were not significant, both $P's > 0.05$. Figure 3 shows the mean N170 responses for the gaze stimuli in both conditions averaged across recording channels and hemispheres. Inspection of the grand-averaged responses in Figure 2 also shows prominent P1 responses. Therefore, we analyzed the mean P1 responses within a 70–110 time window in the picture condition and within an 80–120 time window in the live condition to ascertain whether the gaze direction already had an effect at a very elementary processing stage. However, three-way ANOVAs did not show a main effect of gaze either in the picture condition, $F(2,38) = 0.75$, $MSE = 4.46$, $P > 0.05$, or in the live condition, $F(2,38) = 3.17$, $MSE = 5.28$, $P > 0.05$. Nor were there any interactions.

**EPN amplitudes**

In the picture condition, a three-way ANOVA showed a main effect of channel, $F(1,19) = 54.56$, $MSE = 17.44$, $P < 0.001$, indicating larger EPN for temporal channels. Other main effects and interactions were not significant, all $P's > 0.05$. The main effect of channel was also significant in the live condition, $F(1,19) = 72.81$, $MSE = 16.38$, $P < 0.001$. However, in the live condition, there was also a main effect of gaze, $F(1.4,27.0) = 5.88$, $MSE = 13.34$, $P < 0.05$. Pairwise comparisons indicated more negative EPN for direct ($M = 7.68 \mu V$) vs averted gaze ($M = 9.24 \mu V$), $P < 0.01$, and, marginally, for direct gaze vs closed eyes ($M = 8.97 \mu V$), $P = 0.05$. Other main effects and interactions were not significant, all $P's > 0.05$. Figure 3 shows the mean EPN amplitudes for the different gaze stimuli in both conditions averaged across recording channel and hemisphere.

**Valence and arousal ratings**

The results from valence and arousal ratings (scale range: 1–9) are shown in Table 1. In the picture condition there were no significant effects for these ratings, $P's > 0.05$. In the live condition a one-way ANOVA showed a main effect of gaze for the valence ratings, $F(2,38) = 9.09$, $MSE = 0.64$, $P = 0.001$, indicating that direct gaze was evaluated to elicit less pleasant feelings than averted gaze, $P < 0.05$ and closed eyes, $P < 0.01$. Averted gaze elicited marginally less pleasant feelings than did closed eyes, $P = 0.06$. Similarly, for the arousal ratings, there was a main effect of gaze, $F(2,38) = 15.02$, $MSE = 0.61$, $P < 0.01$, indicating that direct gaze was evaluated as more arousing than averted gaze, $P < 0.01$ and closed eyes, $P < 0.001$. Furthermore, averted gaze was evaluated as more arousing than closed eyes, $P < 0.05$. In order to analyze whether the ERP responses were associated with the subjective evaluations we also correlated the mean ERP responses with the valence and arousal ratings. There were no significant correlations in either of the stimulus conditions, $P's > 0.05$.

**DISCUSSION**

The aim of the present study was to examine whether gaze direction has an effect on face-sensitive ERPs and whether the effect differs depending on the presentation mode of the stimulus (live vs picture). As we hypothesized, the N170 and EPN were greater for direct vs averted gaze and closed eyes in the live condition only. Our behavioural data showed that the valence and arousal ratings for direct gaze also differed from those for averted and closed eyes, again, only in the live condition.

A critical question is why we observed the discrimination between gaze directions only in the live condition. The intensified ERPs to direct gaze could possibly be attributed to the heightened social relevance of live faces, which, unlike facial pictures, are actually capable of action. Although a
picture of a face may elicit a variety of cognitive and affective reactions, as numerous behavioural and physiological experiments show, the observer realizes that it cannot communicate physically. Moreover, seeing a live face triggers pondering of the thoughts and intentions of the other person and likely prepares the observer for any actions to come. A facial picture or virtual character does not need to be treated with the same pattern of outcome predictions in mind. Bearing some resemblance to the present study, Shimada and Hiraki (2006) showed in a brain imaging study that infants’ sensory motor activity was greater in response to human actions vs an object movement only when both stimulus types were presented in a live setting, not when presented on a TV screen. Adults’ reactions to person-performed actions were also more prominent in response to live than video-taped actions. The authors suggested that others’ live movements are more salient in attracting observers’ attention, perhaps due to the assumed possibility of social interaction.

Perhaps the live presentation of a face, more than a picture or an animated face, also enhances the self-relevance of the stimulus by heightening the observer’s feeling of being personally involved, and possibly being someone’s target of interest. In our earlier study (Hietanen et al., 2008), we found that a direct gaze presented live resulted in increased ratings of experienced ‘public’ self-awareness, that is, awareness of how one is perceived by others compared to a direct gaze in a picture. The mode of presentation had no effect on the self-awareness related to one’s surroundings or inner feelings. Recently, enhanced EPN to own-face pictures vs other-face pictures was reported (Gunji et al., 2009). Interestingly, this effect was lacking in participants with pervasive developmental disorders characterized by many difficulties, especially in theory of mind skills. It was suggested that the EPN enhancement of one’s own face may have indicated elevated self-awareness. Our results showing enhanced EPN to live direct gaze could also indicate elevated self-awareness in the observer. Further studies are required to investigate whether the level of self-awareness is influenced by another person’s gaze direction. Heron (1970) argues that intimacy between two individuals is fully realized only by mutual gazing (or touching): ‘What I thus meet is the mental glance or the consciousness of the other directed through his eyes’ (pp. 260). This ‘meeting of gaze’ cannot occur with a facial picture or animation. In other words, we can look at but not into that gaze.

However, we want to note that, in certain conditions, virtual humans and human-like characters may also be self-relevant in terms of social interaction and intimacy (Mojzisch et al., 2006; Schilbach et al., 2006); virtual humans can influence, for instance, the patterns of interpersonal distance and the sense of social presence (Bailenson et al., 2001, 2003). Recently, there have been promising ways to study social interaction in conditions enabling ‘online’ social interaction between a human partner and a virtual character whose gaze is responsive to the viewer’s own gaze (Schilbach et al., 2010; Wilms et al., 2010). Contrary to the above-mentioned studies, in the present study, we employed a paradigm in which the participant was not actively engaged in the interaction process. Thus, although our study design enabled eye contact between the viewers, we cannot ascertain the level to which the participants engaged themselves with the other’s gaze. More generally, an interesting question relates to the discussion about the nature of ‘social interaction’ itself: does social interaction require active guiding of the interaction process itself or can mere presence between two persons looking at each other be considered as social interaction (cf. Rizzolatti and Sinigaglia, 2010; Schilbach, 2010; Sinigaglia, 2010). It is evident that more studies examining the experienced presence and the neural correlates of seeing and interacting with a live person vs a responsive virtual human partner are warranted.

At the neural level, the amygdala seems to play a prominent role in facilitating the early encoding and selection of behaviourally relevant social and emotional information (Fitzgerald et al., 2006; Kleinhans et al., 2007; Ousdal et al., 2008), and the amygdala has been shown to be activated more by direct than avverted gaze (Schilbach et al., 2001, 2003). Recently, there have been promising ways to study social interaction in conditions enabling ‘online’ social interaction between a human partner and a virtual character whose gaze is responsive to the viewer’s own gaze (Schilbach et al., 2010; Wilms et al., 2010). Contrary to the above-mentioned studies, in the present study, we employed a paradigm in which the participant was not actively engaged in the interaction process. Thus, although our study design enabled eye contact between the viewers, we cannot ascertain the level to which the participants engaged themselves with the other’s gaze. More generally, an interesting question relates to the discussion about the nature of ‘social interaction’ itself: does social interaction require active guiding of the interaction process itself or can mere presence between two persons looking at each other be considered as social interaction (cf. Rizzolatti and Sinigaglia, 2010; Schilbach, 2010; Sinigaglia, 2010). It is evident that more studies examining the experienced presence and the neural correlates of seeing and interacting with a live person vs a responsive virtual human partner are warranted.

Table 1: Self-rated valence and arousal scores (1 = very unpleasant/low arousal; 9 = very pleasant/high arousal) as a function of stimulus type (eyes: direct, averted and closed) and presentation mode

<table>
<thead>
<tr>
<th>Presentation mode</th>
<th>Valence M (s.d.)</th>
<th>Arousal M (s.d.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>6.47 (1.54)</td>
<td>1.66 (1.07)</td>
</tr>
<tr>
<td>Averted</td>
<td>6.39 (1.48)</td>
<td>1.97 (1.17)</td>
</tr>
<tr>
<td>Closed</td>
<td>6.63 (1.54)</td>
<td>1.41 (1.00)</td>
</tr>
<tr>
<td>Live</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>5.93 (1.65)</td>
<td>2.57 (1.51)</td>
</tr>
<tr>
<td>Averted</td>
<td>6.50 (1.45)</td>
<td>1.90 (1.30)</td>
</tr>
<tr>
<td>Closed</td>
<td>7.00 (1.24)</td>
<td>1.22 (1.01)</td>
</tr>
</tbody>
</table>
‘live’ person with direct gaze, a stimulus that should be given a processing advantage in order to effectively decode its meaning.

An interesting question is, of course, why, in a recent study, Conty et al. (2007) did indeed obtain gaze-sensitive ERP results by showing facial pictures, but we did not. A possible explanation may be related to the fact that they utilized face stimuli with dynamic gaze, whereas we presented faces with a static gaze. At a neural level, source localization studies have suggested that the STS region is the main source of N170 response (i.e. Batty and Taylor, 2003; see Rossion and Jacque, 2008 for the other putative sources), and the STS region seems to be activated by socially meaningful motion (Senior et al., 2000; Grossman and Blake, 2002; Proverbio et al., 2009). Also, the source reconstruction of ERPs by Conty et al. (2007) themselves implied that the STS was more active during the direct than averted gaze condition. Moreover, in a neuroimaging study by Pelphrey et al. (2002) using virtual, dynamic gaze stimuli, there was greater activation in the STS to direct vs averted gaze. Thus it is possible that the differential N170 responses to pictorial direct vs averted gaze stimuli in Conty et al. (2007) study reflected the additional effect that the motion processing exerted on N170 responses and, possibly, on experienced social relevance of the pictorial stimuli. Instead, the present results show that, although motion is important in understanding facial cues (Ambadar et al., 2005), even static gaze direction stimuli, when presented live, may have an effect on ERPs. In the future, it would obviously be useful to compare ERPs to pictorial vs live faces, both with dynamic gaze, and to investigate whether both viewing conditions show similar patterns of activation in the STS and other parts of the social brain network.

Regarding the gaze direction effects, our ERP results are consistent with those of Conty et al. (2007), as they found more sensitive N170 amplitudes to faces with direct than averted gaze. Thus, our results support the view that the direct gaze is, perhaps, motivationally such a meaningful stimulus that it is processed more intensely than other gaze directions at a very early face processing stage (cf. Conty et al., 2007). Although our results showed a significant difference between N170 responses to direct and averted gaze, the N170 to closed eyes did not differ significantly from N170 to either; N170 amplitude to closed eyes was between those to direct and averted gaze. We expected greater N170 to direct gaze than both to averted and closed eyes, both representing lower potentiality for interaction and less self-relevance than direct gaze. However, perhaps, closed eyes represent an intermediate condition between direct and averted gaze, also from the point of view of potentiality for interaction. Closed eyes signal neither intention for interaction nor active avoidance of it. Instead, closed eyes may be interpreted as signalling attention towards one’s inner sensations. Earlier ERP/MEG studies involving a closed eyes condition are few and the results remain inconclusive (Watanabe et al. 1999; Taylor et al. 2001b, 2001c). We anticipate forthcoming studies to clarify these issues.

Our behavioural results showed that the direct gaze was rated as more arousing and less pleasant than the averted gaze and closed eyes in the live condition only. We reported a similar finding (direct vs averted gaze) in our earlier study (Hietanen et al., 2007), in which the gaze stimuli were shown for 5 s. We suggested that the less positive evaluations of direct than averted gaze may have reflected the long eye contact experienced as somewhat unnatural or intrusive. Now we found a similar result with a stimulus duration (500 ms) corresponding to a sudden glance from a stranger in everyday life. In regular conversation, the normal duration for mutual glance is even longer, around 1.5 s (Argyle, 1981). Thus, in the present type of an experiment, the gaze duration does not seem to affect the valence evaluations. The finding that facial pictures did not have any gaze-sensitive effects on the behavioural ratings may reflect a lack of social and personal relevance in facial pictures. It is noteworthy that in our earlier study (Hietanen et al., 2008) as well as in the present study the participants did not evaluate the characteristics of the stimulus faces, but their own feelings evoked by viewing these. In studies in which the stimulus faces were evaluated, pictures of faces with eyes shifting toward the participant (in 2 s) were rated as more likeable than faces shifting their gaze in the opposite direction (Mason et al., 2005), and likeability of virtual reality faces has been reportedly better for direct than for averted gaze shift (Kuzmanovic et al., 2009). These likeability ratings also increased with the duration of direct gaze (1–4 s). Eyes shifting towards a participant may be considered to be an active expression of interest, resulting in more positive evaluations than an averted gaze shift. Also, the fMRI results of Kuzmanovic et al. (2009) suggested that the longer the gaze duration, the more sophisticated mentalizing abilities were required. Hence, the longer the gaze the more profound the experienced self-involvement. However, in light of our present behavioural results we suggest that when the direct gaze is presented live, even briefly, the level of self-involvement may be high without an uneasy feeling of being stared at.

In the present study, we used faces of females only, yet gender, and more specifically sexual preference, seems to affect face perception. It has been shown that women, in general, are behaviourally more sensitive to eye contact than men (Gueguen and Jacob, 2002), and that in the reward areas of the brain (ventral striatum), the effect of gaze direction is dependent on the sexual relevance (Kranz and Ishai, 2006) and attractiveness (Kampe et al., 2001) of the faces. Gaze direction has also been shown already to interact with facial expression (Adams and Kleck, 2003, 2005; Lobmaier et al., 2008; Doi and Shinohara, 2009), in the early visual processing stages (Klucharev and Sams, 2007). Perceiving another person’s intentions from the face relies heavily on combining information from both the facial expressions and gaze direction. It is possible that a
threatening or otherwise particularly significant facial expression with a direct gaze enhances the self-relevance of the face.

To summarize, the present study showed that a face with a direct gaze elicited stronger early-stage ERP responses than a face with an averted gaze, but only when the face was seen live. The enhanced early response to a direct gaze may facilitate the processing of facial information and subsequent processing of affective and motivational signals sent by the person observed, which, in turn, will facilitate further planning of behaviour. Facing a live person with a direct gaze is likely to create sensations of intimacy and enhance the experienced self-relevance and awareness of how one is seen by others. Our study could potentially contribute to the designing of computerized representations of others to evoke social presence. According to Biocca (2003), this is an intensively pursued design goal in areas such as high-speed teleconferencing systems, social robots and embodied agents. The experimental approach of the present study could possibly help researchers in designing virtual human presentation by suggesting that using a live human as a yardstick is a fairly precise way to test the social presence and ‘humaness’ of the virtual characters evoked. Evidently, in the field of social neuroscience, there is a growing need for studies comparing intra- and inter-personal processes when interacting with physical and virtual others.

Conflict of Interest
None declared.

REFERENCES


