FRONTAL ELECTROENCEPHALOGRAPHIC ASYMMETRY IN RESPONSE TO DIRECT AND AVERTED GAZE IN PICTORIAL AND REAL-LIFE CONDITIONS

University of Tampere
Department of Psychology
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Kati Linna-aho
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UNIVERSITY OF TAMPERE
Department of Psychology

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As a social signal, direction of gaze has been shown to be associated with motivational tendencies to approach and avoid. Direct gaze has been linked to approach tendency and positive affect, whereas averted gaze has been linked to avoidance tendency and negative affect. Studies have revealed important functional differences between the left and right frontal cortex in the processing of motivational and emotional stimuli, with the left frontal cortex showing greater responses to approach-related orientation and the right frontal cortex showing greater responses to avoidance-related orientation.

The past research has generally investigated frontal EEG asymmetry in the context of emotion. The present study investigated frontal EEG asymmetry in response to faces with direct and averted gaze. As a control stimulus, a radio oriented straight or averted was included. The responses to the facial and control stimuli were investigated in two different conditions of presentation: live and on a computer screen. The participants' subjective evaluations of emotional valence and arousal to the stimuli were also investigated. Based on earlier results, it was expected that greater left frontal activation would be obtained to direct gaze, and greater right frontal activation would be obtained to averted gaze. Furthermore, it was assumed that the differences in EEG responses between direct and averted gaze would be larger in the live than the computer condition.

As expected, greater left frontal activation was obtained to direct gaze and greater right frontal activation was obtained to averted gaze in the live condition. Surprisingly, no effects were found in the computer condition. The finding is probably due to lack of social significance conveyed by pictures of faces. The control stimulus did not produce effects in the live or computer conditions. The evaluations of subjective experience revealed a significant effect in response to gaze direction in the live condition. Direct gaze was associated with lower levels of pleasantness and higher levels of arousal in contrast to averted gaze. Again, no effects were found in the computer condition. This applied also for the control stimulus on both conditions. The results demonstrate that direct and averted gaze triggers distinct patterns of neural activity in accordance with approach and avoidance motivational orientations.

KEY WORDS: Gaze direction, EEG asymmetry, live stimulus, approach-avoidance motivation

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1. INTRODUCTION

Eye gaze is an important social signal in human interaction. It is therefore not surprising to discover an abundant number of studies around the topic from developmental studies to studies investigating nonhuman primates and clinical populations, as well as adult individuals. Individuals are highly sensitive to nonverbal cues that provide information about other individuals. The accurate perception and analysis of eye gaze cues is an important component of social interaction, and has been at the centre of psychologists' interest for decades. Studies have also sought for physiological correlates of eye gaze perception, using measurements of skin conductance, heart rate, and electroencephalograph, for instance. Gaze direction signals another individual's focus of attention and operates as a key to establishing joint attention. Eye gaze can also give information about an individual's emotional state or motivation to approach or avoid. Converging evidence has identified a specialized neural system for perceiving eyes and gaze direction.

1.1. The social role of gaze

The importance of eye gaze is underscored by evidence that already in early infancy babies tend to prefer facial (Mondloch et al., 1999) and eye stimuli (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000), and have the ability to detect the gaze direction of another person, with a preference for direct gaze (Farroni, Csibra, Simion, & Johnson, 2002; Farroni, Massaccesi, Menon, & Johnson, 2007). Studies suggest that we might have an innate tendency to detect socially relevant information.

Information gained from the eyes serves a number of different functions (see Kleinke, 1986). Gaze behavior regulates turn-taking in a conversation, expresses intimacy, communicates mental state, or is used to serve some purpose (e.g., desire for ingratiate, convince, or deceive). Direct gaze often signals positive feelings, such as closeness, liking, and attraction. Several studies show that individuals spend more time looking at individuals they like than individuals they dislike (e.g., Mehrabian, 1968). Individuals are also considered more favorable when they engage in high rather than low levels of gaze with an interactant (Argyle, Lefebvre, & Cook, 1974; Napieralski, Brooks, & Droney, 1995). Furthermore, the amount of direct gaze appears to be correlated with judgements of an individual's level of self-esteem (Angus, Osborne, & Koziey, 1991). With direct gaze we also express that our attention is directed to the speaker. At the same time the speaker is informed that he/she is attended to and that he/she is understood. By looking away from the speaker a hearer might show a lack of interest. However, direct gaze can also result in negative evaluation of an interactant. If an individual looks for a greater proportion of the time than the norms for the situation permit he/she may be seen as intrusive (Argyle et al., 1974). A stare from a stranger or a prolonged and unexplained gaze can be understood as threatening (Argyle & Cook, 1976; Ellsworth, Carlsmith, & Henson, 1972). Averted gaze, on the other hand, has been related to factors such as submissiveness, appeasement (see Kleinke, 1986) and embarrassment (Edelmann & Hampson, 1981).

There appear to be gender differences associated with gazing behavior. Research indicates that women generally gaze more in social interaction than men (Argyle & Cook, 1976; Leeb & Rejskind, 2004). Furthermore, women tend to have more tolerance and more favorable responses than men when receiving gaze from others (see Kleinke, 1986). These differences have been attributed to learned sex roles resulting in women being more thoughtful and sensitive (Ellsworth & Ludwig, 1972), although it has been suggested that the differences might be in part biological in origin. Connellan, Baron-Cohen, Wheelwright, Batki, and Ahluwalia (2001) showed that 1 day old female neonates looked more at a face, while males showed stronger interest in mechanical objects. Furthermore, the amount of gaze contact shown by infants at 12 months of age has been found to be inversely related to prenatal testosterone (i.e., the more gaze contact the less prenatal testosterone), and prenatal testosterone is higher in males than females (Lutchmaya, Baron-Cohen, & Raggatt, 2002).

1.2. Attention orienting and gaze direction

The ability to determine accurately where another individual is looking is considered to be an important social and cognitive skill (Argyle & Cook, 1976). Individuals are highly proficient at discriminating the direction of another individual’s gaze (Gibson & Pick, 1963; Vecera & Johnson, 1995), and this ability emerges early in life (Farroni et al., 2002; Vecera & Johnson, 1995). Compared with other primates, humans have eyes with a relatively small region of dark (the pupil and iris) surrounded by large regions of white (sclera) on the both sides of the iris. It may well be that human eye morphology has evolved to allow easy discrimination of small changes in the gaze direction of another individual (Kobayashi & Kohshima, 1997).

The direction in which another individual is gazing tends to shift our own attention to the same direction, leading to a phenomenon called joint attention (Baron-Cohen, 1995). Several studies investigating the cognitive mechanisms underlying attention shifts in response to observed gaze direction have been reported. It has been shown that a face looking at the side of the screen where an object is to appear facilitates responses to this cued object as compared with objects appearing in uncued positions (Friesen & Kingstone, 1998; Hietanen, 1999). Furthermore, this effect has been shown to be mainly automatic and hard to control voluntarily, since it persists even if the participants are asked to ignore the face or when they are informed that the object is more likely to appear on the uncued side (Driver et al., 1999; Friesen, Ristic, & Kingstone, 2004). This cueing effect can be observed as early as at 3 months of age (Hood, Willen, & Driver, 1998). Note, however, that the perceived direction of gaze is not entirely independent of facial context as the orientation of the head can also modulate the perceived direction of attention (Langton, Watt, & Bruce, 2000), although observers seem to be extremely sensitive to gaze direction (Anstis, Mayhew, & Morley, 1969).

Gaze does not only act as an indicator of where another individual is looking, but it also signifies that something at this location has captured his/her attention, thus, implying that the individual may have some intention or goal towards this particular location. Gaze direction, thus, engages the mechanisms involved in the attribution of other individuals' thoughts and intentions, a mechanism that is generally known as the theory of mind (Baron-Cohen, 1995; Calder et al., 2002). Furthermore, as a matter of course, individuals look at objects rather than empty space. Lobmaier, Fischer, and Schwaninger (2006) found that the presence of an object nearby the observed location causes the perceived gaze direction to gravitate toward the object. Pelphrey, Singerman, Allison, and McCarthy (2003) has demonstrated that neural activity in response to faces with averted gaze is modulated depending on whether the gaze is directed towards an object or an empty space. These findings, thus, indicate that gaze processing is influenced by the perceived goal of action and therefore context sensitive.

Of particular interest, individuals are especially sensitive when someone's attention is directed at them. It has been shown that during visual search, eyes that are looking at the observer are detected faster than eyes directed elsewhere (Conty, Tijus, Hugueville, Coelho, & George, 2006; Senju, Hasegawa & Tojo, 2005; von Grünau & Anston, 1995). This has been considered to reflect the efficacy for detecting socially important signals. The sensitivity to direct gaze is highlighted by the notion that while individuals are generally highly accurate in assessing whether another person's gaze is directed at them, these judgements tend to be biased when the observed face is slightly deviated to the left or the right (Cline, 1967). In other words, if another individual is looking roughly at you, you are likely to assume he/she is looking directly at you. This self-referential bias has been shown to be more pronounced with schizophrenia patients (Hooker & Park, 2005; Rosse, Kendrick, Wyatt, Isaac, & Deutsch, 1994) often characterized as suffering from impairments in social cognition. Martin and Rovira (1982) found that while the participants were highly accurate of gaze direction judgements, smiling face led to a response bias, in that, the participants reported more gaze contact from smiling than non-smiling faces.

1.3. Gaze contact

As already noted, direct gaze has been shown to be a particularly salient stimulus for observers as compared to averted gaze (e.g., von Grünau & Anston, 1995) and can convey a variety of meanings, such as signaling attraction, aggression, or a desire to communicate, depending on the context. Direct gaze is always a precursor to social interaction between individuals (Baron-Cohen, 1995; Kleinke, 1986), and seems to be predominant compared to other eye cues in the initial encounter of another individual (Angus et al., 1991). Further emphasizing the importance of direct gaze as an essential social cue, a recent event-related potential study demonstrated that direct gaze employed more neural processing resources as compared to other gaze directions in the early stage of gaze direction processing (Conty, N'Diaye, Tijus, & George, 2007). Observing direct gaze can capture attention to the targeted face that can result in delayed orienting of attention toward peripheral cues as compared with averted gaze or closed eyes (Senju & Hasegawa, 2005). Direct gaze can also prolong gender judgements of faces (Vuilleumier, George, Lister, Armony, & Driver, 2005), although conflicting results have been reported (Macrae, Hood, Milne, Rowe, & Mason, 2002). Generally, these effects have been attributed to deeper face processing, probably due to the social significance of gaze contact (e.g., George, Driver, & Dolan, 2001). The majority of the clinical conditions characterized by social withdrawal (e.g., social phobia, schizophrenia, and autism) have among their symptoms the avoidance of direct gaze (Horley, Williams, Gonsalvez, & Gordon, 2003; Phillips, Baron-Cohen, & Rutter, 1992).

Many theories of gaze interaction assume that direct gaze is physiologically arousing (Argyle & Dean, 1965; Kendon, 1990). Nichols and Champness (1971) reported increases in galvanic skin response (GSR) in response to direct gaze when the participants continuously gazed at the experimenter's eyes who alternately averted his eyes and returned his gaze. Gale, Spratt, Chapman, and Smallbone (1975) found higher electroencephalographic (EEG) arousal in response to the experimenter's direct gaze. In addition, EEG arousal was found to weaken as a function of distance, but the effect was always higher for direct than averted gaze, whatever the distance. Kleinke and Pohlen (1971) found higher heart rate in participants playing a game with a partner who gazed at them as compared to a condition without gaze contact. However, there exist studies reporting only marginal effects (Donovan & Leavitt, 1980) or no effects of direct gaze on physiological arousal (Kylliäinen & Hietanen, 2006; Martin & Gardner, 1979). In the study by Nichols and Champness (1971), the duration of gaze contact was 10 seconds for each period, which can be considered as exceptionally long. Thus, the results can be argued to be explained by the strangeness of the experimenter's behavior rather than his gaze per se. However, Gale et al. (1975) obtained higher EEG arousal effects in response to direct gaze with only 3-second duration of gaze contact. Therefore, the differences in the results between the studies might be owing to the fact that the studies showing greater arousal effects to direct than averted gaze employed real individuals as stimuli, while the studies showing only minor effects or no effects used images of faces with no real reciprocal interaction.

Direction of gaze changes in a relatively regular manner in an interaction (Kendon, 1990). During conversation, the amount of gaze contact is inversely related to the amount of emotionality displayed by the participants. For example, the more smiling there is, the less time the interactants spend in gaze contact. Kendon (1990) suggests that this, rather surprising occurrence, might be associated with the regulation of emotional arousal. For any given encounter there is a limit to the level of emotionality that is 'acceptable'. Gaze contact in itself has an arousal provoking component. If emotionality threatens to rise too high, there must be some device whereby the excitement can be lowered. The aversion of gaze, as Kendon proposes, may be one device whereby this regulation can be achieved.

1.4. Approach-avoidance motivation, emotion and gaze direction

Gray (1994) has proposed that there exist two general motivational systems that underlie behavior and affect: a behavioral activation system (BAS) and a behavioral inhibition system (BIS). The BAS is thought to be an approach system that responds to positive incentives by activating behavior. The BIS, on the other hand, inhibits behavior in the presence of cues that signal potential aversive consequences, such as fear of rejection by someone. Gaze behavior has been linked to both approach-avoidance motivational orientations and emotion. A great number of evidence show that certain patterns of gaze behavior and facial expressions of emotion co-occur in human interaction (see Argyle & Cook, 1976), and that they can function as a cue to an individual’s behavioral intentions to approach or avoid. Generally, it has been demonstrated that approach-oriented emotions, such as happiness, love and anger, have a tendency to be expressed more with direct gaze, whereas avoidance-oriented emotions, such as embarrassment and disgust, tend to be expressed more with averted gaze (see Argyle & Cook, 1976; Kleinke 1986). Kimble, Forte, and Yoshikawa (1981) have shown that when communicating messages of strong emotional intensity, individuals tend to express increased amount of direct gaze, regardless of whether the emotional expression is positive or negative.

More recent studies have investigated the effects of gaze direction on the perception of emotional expression. Intuitively, one could imagine that seeing a face with direct gaze would facilitate the processing of facial displays of emotion. Interestingly, it has been shown that the influence of gaze direction on the perception of facial displays of emotion actually varies depending on the motivational orientation associated with the emotion being expressed. Adams and Kleck (2003) found that approach oriented facial expressions of anger and happiness are perceived more quickly when displayed with direct rather than averted gaze, whereas avoidance oriented facial expressions of fear and sadness are perceived more quickly when displayed with averted rather than direct gaze. In their later studies, Adams and Kleck (2005) found that direct gaze also increased the misjudgements of approach oriented emotions of anger and joy, whereas averted gaze increased the misjudgements of avoidance oriented emotions of fear and sadness, even in a situation, where the stimulus faces were actually neutral displays, i.e., devoid of any expressive information. These findings suggest that both emotional expression and gaze behavior convey basic behavioral motivations to approach and avoid. In addition, the notion of gaze direction and facial expression combination in the perceptual processing and interpretation of emotion suggests a process that is highly developed. Although, as Adams and Kleck (2005) denoted, it cannot be entirely ruled out that the findings arose from the fact that people are used to seeing certain patterns of gaze direction co-occurring with certain emotional displays. Thus, seeing these cues paired differently may violate our expectations, and leading to prolonged judgements.

1.5. The neural basis of gaze perception

Given the wealth of information present in the human face and its importance in social processing, considerable effort has been applied to understand the neural mechanisms that underlie face and gaze perception (see Emery, 2000). Face and object recognition involves qualitatively different processes and they take place in distinct brain areas (Kanwisher, McDermott, & Chun, 1997). It has been proposed that after a general low-level analysis, facial information processing continues with two distinct pathways, with other processing viewer-independent or invariant aspects of face (such as gender and identity) and the other viewer-dependent or changeable aspects of faces (such as facial expression and gaze direction) (Bruce & Young, 1986; Haxby, Hoffman, & Gobbini, 2000). There is increasing evidence suggesting that the superior temporal sulcus (STS) (Akiyama et al., 2006; Calder et al., 2007; Engell & Haxby, 2007; Hooker et al., 2003; Pelphrey et al., 2003; Pelphrey, Viola, & McCarthy, 2004) is involved in gaze processing. In addition, it has been shown that the subcortical structure amygdala may also be sensitive to gaze direction (Kawashima et al., 1999).

The STS region specifically seems to be involved with the analysis of directional information, gaze motion, and more generally, stimuli that signal the actions of another individual (Allison, Puce, & McCarthy, 2000). A fMRI study conducted by Puce, Allison, Bentin, Gore, and McCarthy (1998) showed significant activity within the posterior STS for eye and mouth movements but not for nonsocial, moving stimuli. Pelphrey et al. (2003) recorded a significantly larger hemodynamic response in the right hemisphere STS for a face stimulus in which the eyes shifted compared with the same stimulus with static eyes. Pelphrey et al. (2004) found greater activity in the STS to direct gaze than to averted gaze.

While the STS seems to have a primary role in perception of dynamic facial features, Haxby et al. (2000) have proposed that the ventral temporal cortex, including the fusiform gyrus, might have a special role in the perception of facial features that are invariable over dynamic changes (e.g., identity). Hoffman and Haxby (2000) showed that the STS and intraparietal sulcus were more activated when subjects judged seen gaze direction, whereas face identity judgements for the same stimuli produced relatively more fusiform gyrus activity. George et al. (2001) found that specific regions of the fusiform gyrus yielded stronger responses to faces with direct relative to averted gaze, regardless of seen head orientation. The authors suggested that the result may be interpreted in terms of enhanced attention and deeper encoding for faces with direct (relative to averted) gaze, due to the social significance of gaze contact.

The data regarding the role of the amygdala have largely been confined to emotion processing. However, besides to being sensitive to changes in facial expression, the amygdala also seems to be sensitive to gaze direction (Hooker et al., 2003; Kawashima et al., 1999). Kawashima et al. (1999) found significant activation in the amygdala using the positron emission tomography during a gaze discrimination task (gaze contact versus no gaze contact). The activation was lateralized to the left amygdala during both conditions, but the right amygdala was specifically activated only during the gaze contact task. This may not indicate that the amygdala is essential for the discrimination of gaze direction per se, but that direct gaze is emotionally significant. Adams, Gordon, Baird, Ambady, and Kleck (2003) reported different amygdala activity in response to faces displaying anger or fear depending on the gaze direction. Amygdala activity was less prominent in situations that clearly signal a threat in the environment (e.g., a fearful face with averted gaze), or a threat to an observer (e.g., an angry face with direct gaze), than it was in situations in which the source of threat required additional interpretation by the observer (e.g., an angry face with averted gaze or a fearful face with direct gaze). The authors suggested that the amygdala may play a special role in processing threat-related ambiguity and that gaze direction is highly relevant in resolving such ambiguity.

1.6. Frontal EEG asymmetry, motivation and affect

Over the past two decades, a great number of research has been devoted to investigate the relationship between frontal electroencephalogram (EEG) asymmetry and different aspects of emotion and motivation. Contrary to more simplistic notions of the right hemisphere superiority across all domains of emotion, research has proposed that the left and the right frontal cortical regions are differentially associated in emotional and motivational processes. Generally, it has been suggested that the left frontal activity is associated with positive emotions and approach motivation, whereas the right frontal activity is associated with negative emotions and avoidance motivation (see Coan & Allen, 2004; Harmon-Jones, 2004 for reviews).

Frontal EEG asymmetry has been investigated in several contexts. Studies examining the relationships between baseline activation and individual differences have shown that baseline activation behaves like a trait, it demonstrates acceptable temporal consistency (Tomarken, Davidson, Wheeler, & Kinney, 1992). Positive trait affect has been associated with greater left than right frontal activity, and negative trait affect has been associated with greater right than left frontal activity (Davidson & Fox, 1989; Tomarken, Davidson, Wheeler & Doss, 1992). Schmidt (1999) found that shyness was associated with greater right than left frontal activation, whereas sociability was associated with greater left than right frontal EEG activation. Sutton and Davidson (1997) investigated the relation between EEG frontal activation and self-reported approach-avoidance tendencies using the BIS/BAS–scales (Carver & White, 1994). They found that greater left frontal activation was associated with trait tendencies to approach, whereas greater right frontal activation was associated with trait tendencies to avoid. Coan and Allen (2003) confirmed these results for the approach tendency, but not for the avoidance tendency, suggesting that behavioral avoidance is likely to be more complex.

Studies examining the relationships between baseline frontal activation and responses to emotion-eliciting stimuli have discovered that baseline frontal activation can predict individuals' emotional responses. Generally, individuals with greater left than right frontal baseline activation have been shown to be more responsive to positive stimuli, whereas individuals with greater right than left frontal baseline activation have been shown to be more responsive to negative stimuli. Davidson (1998) has stressed that frontal asymmetries are best understood as a hereditary disposition, in that, individual differences in frontal asymmetry are not sufficient to cause a specific emotional state but, rather, they predispose the individual to respond under certain conditions with approach- or avoidance-related emotion. Davidson and Fox (1989) recorded baseline EEG frontal activity from 10-month-old infants. Infants who showed greater right frontal activation during baseline cried when separated from their mothers, while infants who showed greater left frontal activation did not cry in response to maternal separation. Similarly, Tomarken, Davidson, and Henriques (1990) found that adults with relatively greater right than left frontal activity showed larger negative affective responses to negative emotion-inducing films (fear and disgust) and smaller positive affective responses to positive emotion-inducing films (happiness).

Research on clinical populations has shown that depressed individuals tend to show relatively less left than right frontal activity (Gotlib, Ranganath, & Rosenfeld, 1998). The relation has also been found with previously depressed individuals (Gotlib et al., 1998; Henriques & Davidson, 1990), indicating state-independency. Although this conflicts with the study by Debener et al. (2000), who found increased variability amongst depressed patients as compared to healthy individuals. Davidson, Marshall, Tomarken, and Henriques (2000) found that individuals with social phobia showed large increases in right-sided frontal activation compared to control subjects when they anticipated making a public speech, though they did not differ from control subjects at baseline.

Studies examining frontal EEG asymmetry in response to emotion-eliciting manipulations (e.g., manipulation of a participant's facial expression) have indicated that left frontal activation is associated with approach-related positive emotion (such as joy and interest) and right frontal activation is associated with avoidance-related negative emotion (such as sadness and disgust) (Coan, Allen, & Harmon-Jones, 2001; Davidson, Ekman, Saron, Senulis & Friesen, 1990; Harmon-Jones, Vaughn-Scott, Mohr, Sigelman & Harmon-Jones, 2004). Studies investigating frontal EEG asymmetry in response to emotion-eliciting stimuli have reported comparable results. For example, 10-month-old infants showed greater left than right frontal activation in response to a film clip of an actress generating a happy facial expression as compared to a sad facial expression (Davidson & Fox, 1982). In a study by Schmidt and Trainor (2001), the participants showed greater left than right frontal activation during the presentation of positively valenced (joy and happy) musical excerpts and greater right than left frontal activation during the presentation of negatively valenced (fear and sad) musical excerpts. Furthermore, the participants showed significantly greater overall activity in the frontal region of the brain as the affective musical stimuli became more intense.

There has been a debate of whether the frontal asymmetry is solely due to motivational tendencies, emotional valence, or both. Often, positive emotion is associated with approach-related motivation and negative emotion is associated with avoidance-related motivation. However, in recent years, increasing evidence has begun to appear indicating that anger, as thought to be a negative emotion, seems to produce greater left than right frontal activity (Harmon-Jones, 2003; Harmon-Jones, 2004). Harmon-Jones and Allen (1998) investigated the relationship between resting frontal asymmetrical activity and self-reported trait anger, and found that trait anger was associated with greater left than right frontal activation. Harmon-Jones and Sigelman (2001) found that situationally induced anger by means of personal insult increased relative left frontal activation. Moreover, the participants who were insulted reported being more angry and behaved more aggressively towards the person who insulted them as compared to participants who were treated in a neutral manner. These findings fit the approach-avoidance dimension since anger has an approach-oriented tendency, in that, it prepares an organism to approach for a fight (Fox, 1991). Nonetheless, they are clearly conflicting with the positive-negative valence theory. It has been proposed that frontal asymmetry of emotion may have evolved to exclude conflicts among action tendencies (Davidson, 2004). Van Honk and Schutter (2006) pointed out that some positive emotions (such as happiness) are rather states of well-being that requires balance between affective approach and avoidance, and thus, offers no reason to be processed asymmetrically in the frontal cortex. To directly address this question, van Honk and Schutter (2006) used repetitive transcranial magnetic stimulation (rTMS) to locally decrease the activation of the left or the right frontal cortex. After real or fake stimulation, the participants performed an emotional memory task that consisted of a set of pictures of either angry and neutral or happy and neutral faces. Deactivation of the left frontal cortex by rTMS significantly decreased the processing of anger as compared to both fake stimulation and the stimulation of the right frontal cortex. However, neither left nor right frontal cortex deactivation influenced the processing of happiness. The finding, thus, seems to support the motivational direction model rather than the emotional valence model.

1.7. Presentation mode of social stimuli

Observation of human behavior in everyday settings has been considered to be problematic since, in the real world, stimuli and behavior are complex and difficult to control. Most existing studies investigating gaze perception have used stimuli such as pictures, videotapes or animated figures, that is, non-real-life objects for obvious reasons of usability and experimental control. However, it has been argued that gaze processing might be influenced by the social context in which individuals operate (Ellsworth & Langer, 1976; Martin & Gardner, 1979). Furthermore, as noted, studies have revealed larger arousal effects in response to direct gaze with a real-life individual (e.g., Gale, et al., 1975), while studies using pictorial stimuli have not been able to reaffirm the results (e.g., Donovan & Leavitt, 1980). Interaction with a real individual is always a two-way process, in that, the person is at the same time an observer and observed. An image of a face, on the contrary, does not enable reciprocity. Therefore, one might argue that the responses to gaze direction of another individual by means of pictorial stimuli cannot entirely be generalized in to everyday gaze perception. For this reason, in order to create a setting that has more resemblance to normal interaction between individuals, the present study included a real-person stimulus. The aim was to investigate whether there is a difference between the reactions to an individual who is actually present, thus, capable for real interaction, and reactions when the observer is only seeing an image of a face.

The use of pictorial stimuli allows the experimenter to have accurate control over the experimental procedure, including the regulation of parameters such as the onset or duration of the stimuli. Usually this kind of precision would be difficult to attain with a live individual as a stimulus. The present study, however, employed a liquid crystal (LC) shutter placed between the stimulus person and the participant. This optical shutter can be made opaque or transparent within a millisecond range, thus, offering a practical way to present both stimuli, pictorial and live, with an exact control of timing.

1.8. Aims of the study

The present study investigated hemispheric EEG asymmetry in response to direct and averted gaze with a neutral facial expression. Based on earlier results, it was expected that greater left frontal activation would be obtained to direct gaze in conjunction with approach-related orientation and greater right frontal activation would be obtained to averted gaze in conjunction with avoidance-related orientation. In order to verify face specificity, a radio oriented straight or averted was included as a control stimulus. The responses to the facial and control stimuli were investigated in two different conditions of presentation: live and on a computer screen. It was assumed that the differences in EEG responses between direct and averted gaze would be larger in the real-life than pictorial stimulus condition. Furthermore, the participant's subjective evaluations of emotional valence and arousal were also investigated in all four conditions (live face, live radio, computer face, computer radio).

2. METHOD

2.1. Participants

26 students from Tampere University (13 women and 12 men) participated in the study. They received course credit for their participation. The data of 6 participants were excluded from the final analyses due to unsatisfactory impedance level, excessive movement artifacts, participant's medical condition, or equipment problems. Thus, 20 participants (all right handed) were included in the study, 12 of them being women and 8 men. The participants ranged in age from 20 to 40 years, with a mean age of 24,8.

2.2. Stimuli and procedure

The participants were shown faces of the two female experimenters gazing either straight or averted 30° to the left or the right. The facial stimuli were devoid of emotional information, i.e., neutral displays. In addition, a radio oriented either straight or averted 30° to the left or the right was used as a control stimulus (see Figure 1). The stimuli were presented in two different conditions: live and on a computer screen. In the computer condition, the stimuli were colour pictures of the two female experimenters gazing straight or averted and a colour picture of a radio oriented straight or averted. In the live condition, the participants were shown faces of the same female experimenters gazing straight or averted and a radio oriented straight or averted. Hence, a total of nine different pictures in the computer condition and nine different displays for the live condition were used. The visual stimuli were set to be approximately 12° of visual angle in size for both conditions. Stimulus presentation and data collection were controlled by NeuroScan 4.3 software.

In the computer condition, the participant sat in front of a computer screen, at a distance of 70 centimetres. The stimuli were presented in the center of a 17-inch computer monitor. In the live condition, a window with a voltage sensitive liquid crystal shutter (LC-TEC Displays Ab) was located between the participant and the stimulus person. The LC shutter could be switched between opaque or transparent state within a millisecond range. The shutter was 30 x 40 cm in size and was attached to a white panel (100 x 80 cm). The shutter was kept opaque during the inter-stimulus-intervals (ISI). During this time the stimulus person turned her gaze to the appropriate direction or silently moved the radio following a script. During stimulus presentation, the stimulus person made an effort to keep her expression as neutral as possible and avoided blinking. In order to eliminate potential mimicking of the facial expressions of the participant, the stimulus person looked at her own eyes reflected from the window. The lighting conditions in the laboratory were such that the stimulus person was unable to accurately see what the participant was expressing on the other side of the window, while still giving an impression that she is looking directly at the participant. This was confirmed by the participants in the end of the study. The participants could not see their own reflections from the window. Before starting the live-face-condition and to render gaze contact, the seats were set in such a manner that the participant's and the stimulus face's eyes were on the same level with each other.

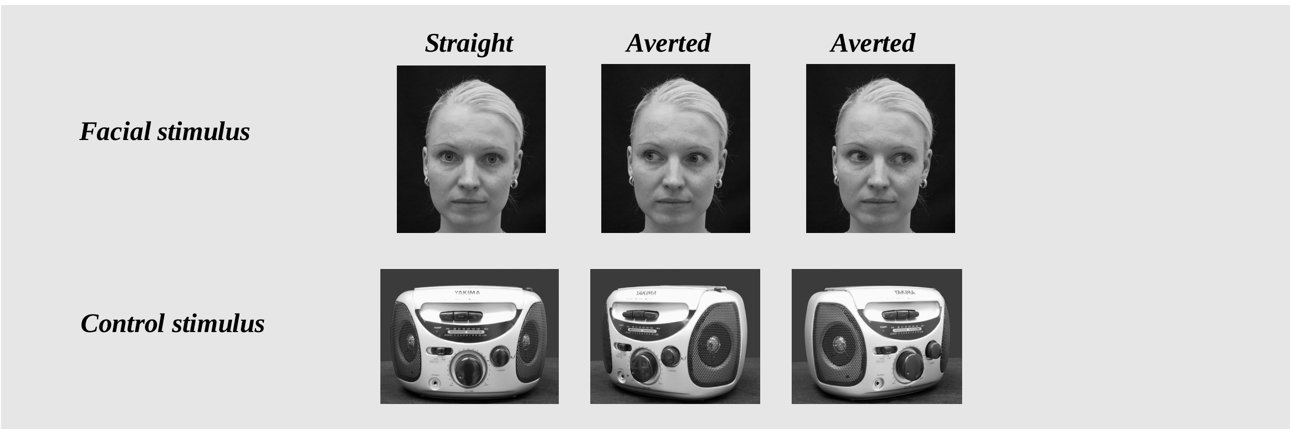

Figure 1. Examples of visual stimuli for the experiment.

Two experimenters carried out the data collection. The measurements included skin conductance responses (SCR), electrical activity of the heart (EKG), electroencephalogram (EEG), and electro-oculogram (EOG). The SCR and the EKG will not be reported here. Each participant was measured individually, and the whole period of testing lasted about 2 hours for one participant. After arriving to the laboratory the participants were first inquired a few background information (e.g., age and handedness). They were informed that the experiment would contain watching visual stimuli on a computer screen or through a transparent/opaque window, while the physiological recordings would be made, and that the experiment would be concluded by filling out a few questionnaires. Upon this, the participants gave their written consent to the study, were briefly introduced to the laboratory, and the electrodes for the physiological recordings were placed.

The experiment began with a 2-minute baseline recording of (resting) EEG. During this time the participants were told to keep their eyes closed. After baseline recording, the participants viewed a series of facial/control stimuli while the EEG was recorded. Prior to the stimulus presentation, the participants were told that the stimuli they would be seeing were faces of the experimenters with eyes gazing straight or averted or a radio oriented straight or averted. The facial/control stimuli were presented sequentially, i.e., first a series of facial stimuli, then a series of control stimuli, or vice versa. Moreover, the two conditions of presentation mode were presented in succession. Half of the participants started with facial stimuli and half with control stimuli. Half of the participants began with the computer condition and half with live condition. The participants were randomly assigned to these orders. To eliminate habituation effects, the face and the radio was different in the computer and live conditions. The participants were instructed to avoid excessive movements and to be as relaxed as possible, keeping their eyes on a screen when stimulus appeared. In order to know when the stimulus would appear, a short tone was presented through a loud-speaker 5 seconds before the stimulus. All visual stimuli appeared for 5 seconds with a 30-45 second ISI between them. Altogether, 12 facial stimuli (6 gazing straight, 3 to the left, 3 to the right) and 12 control stimuli (6 straight, 3 to the left, 3 to the right) were presented in both conditions, constituting four different blocks (live face, computer face, live control, computer control) and summing up to a total of 48 trials for each participant.

2.3. Subjective ratings

Immediately after the EEG recordings, the participants were asked to assess their subjective experience of valence and arousal during each stimulus presentation (computer-face-straight, computer-face-averted, computer-radio-straight, computer-radio-averted, live-face-straight, live-face-averted, live-radio-straight and live-radio-averted) on a pleasant-unpleasant and arousal-calm dimensions. For this purpose, the Self-Assessment Manikin (SAM) was used (Bradley & Lang, 1994). The paper-and-pencil version of SAM is composed of two sets of five figures (manikins), which symbolize the two affective dimensions. Figures representing valence range from a widely smiling (pleasant pole) manikin to a frowning one (unpleasant pole), going through a middle neutral position. Those representing arousal range from a very calm and relaxed, eyes-closed maniking to a highly vigorous and bouncing, wide-open eyes figure. Ratings of each dimension are given in a 9-point format, in which the participants are free to choose any of the five figures or any of the four intervals in between them. After filling out the SAM questionnaire, all the electrical equipment were removed and the participant was permitted to wash up if she/he so desired.

2.4. EEG recording and analysis

Scalp EEG was recorded from four bilateral pairs of electrodes at the frontal (F3, F4, F7, F8), central (C3, C4) and parietal (P3, P4) regions and from one midline electrode (Cz) of the 10-20 electrode system using a stretchable electrode cap (Fz for ground electrode). Both ears were used as a reference site (the 'linked ears' –technique). Vertical and horizontal eye movements (electro-oculograms, EOG) were also recorded for the purposes of artifact removal from the EEG. These electrodes were placed above and below the participants left eye (for VEOG) and beside the outer canthi of each eye (for HEOG). Electrode gel was applied to each electrode, and the scalp at each site was carefully abraded until all EEG electrode impedances were below 5 KΩ (20 KΩ for EOG). Data collection was accomplished with NeuroScan 4.3 software.

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 for off-line analyses. Off-line, the continuous EEG signal was corrected for eye movement artifact using a regression-based blink reduction algorithm (Semlitsch, Anderer, Schuster, & Presslisch, 1986). Other visible artifacts were removed by visual examination. Every artifact-free 5-second stimulus period was segmented into eight 1.024-ms epochs with 50 % overlap between adjacent epochs. Spectral power was calculated for each epoch using Fast Fourier Transform (FFT) with a 10 % Hanning taper. The power spectra obtained were averaged over all artifact-free epochs within each trial and over separate trials within each condition. Trials with less than 50 % artifact-free epochs were excluded from the data. For average power spectra within each condition, power density values (μV^2) within the alpha band (8-13 Hz) were calculated and natural log-transformed to normalize the distributions. Asymmetry scores were calculated for all electrode pairs by subtracting the log-transformed density value for the left site from that for the right site (e.g., log F4 – log F3) (Allen, Coan & Nazarian, 2004). Positive asymmetry scores reflect greater left-sided activation (because alpha power is inversely related to cortical activity) and negative asymmetry scores reflect greater right-sided activation (Davidson, Jackson & Larson, 2000; Oakes et al., 2004).

2.5. Data analysis

Since the majority of studies show frontal EEG asymmetry on the dorsolateral prefrontal area (electrode positions F3 and F4, according to the international 10-20 system), the analyses were restricted to the electrode pair F3/F4. A 2 x 2 x 2 repeated measures analysis of variance (ANOVA) was used to examine the effects of Condition (computer, live), Stimulus (face, control), and Direction (straight, averted).

3. RESULTS

Hemispheric asymmetry. A summary of the results is shown in Figure 1. A 2 x 2 x 2 repeated measures ANOVA yielded significant main effect for Stimulus, $F(1,19) = 5.19$, $p = .035$. The main effect for Direction was marginally significant, $F(1,19) = 4.27$, $p = .053$. The Condition x Stimulus x Direction interaction was significant, $F(1,19) = 8.28$, $p = .01$. Gender as a between-subjects factor was included, but no effects were found in this regard, and thus, was excluded from further analysis. Because of the three-way interaction, the data were further analyzed separately for each block. As an inspection of the Figure 1 suggests, a significant effect of gaze direction was obtained in the live condition, $t(19) = 2.69$, $p = .01$. Greater left frontal activation was associated with direct gaze and greater right frontal activation was associated with averted gaze. Gaze direction did not have an effect in the computer condition ($p > .7$). For the control stimulus, the orientation had no effect on the asymmetry scores, neither in the live condition ($p > .1$) nor in the computer condition ($p > .07$).

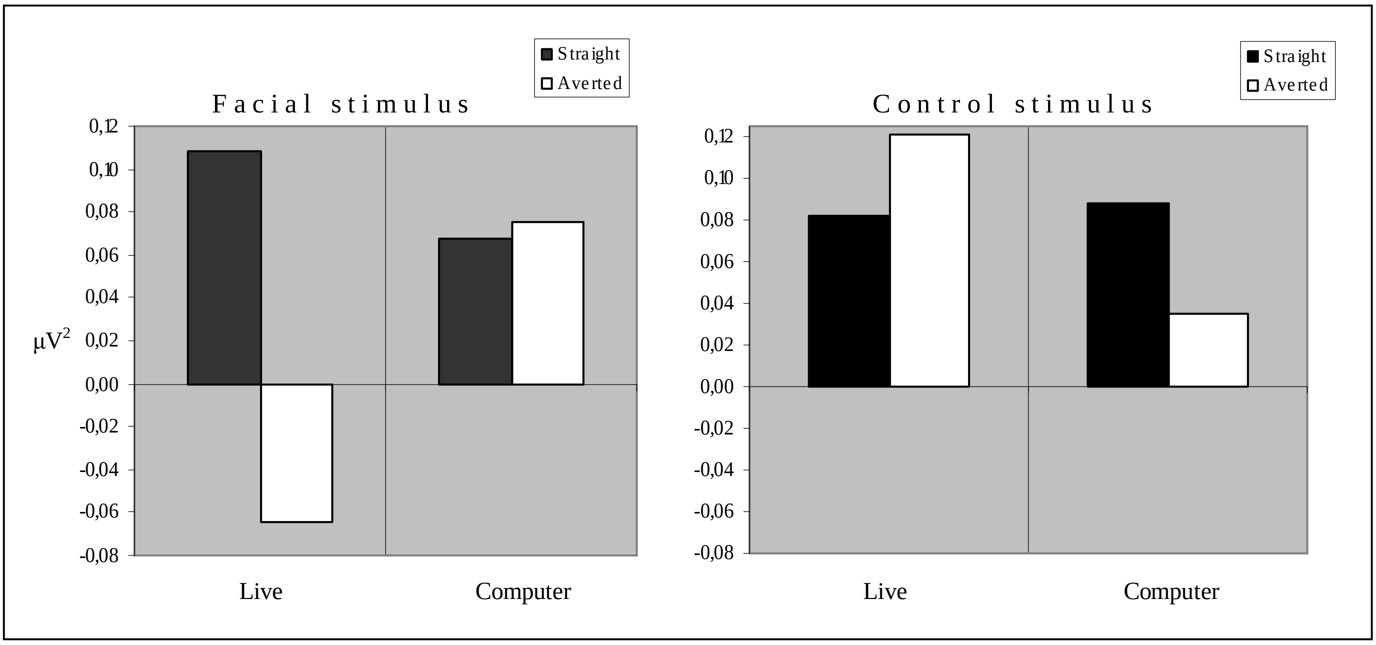

Figure 1. Mean asymmetry scores of power density values within the alpha band (8-13 Hz). Positive asymmetry scores reflect greater left-sided activation and negative asymmetry scores reflect greater right-sided activation.

Self-reported affect (SAM-ratings). The participants assessed their subjective experience of valence and arousal for each stimulus using the SAM-rating scales (see Figure 2 for results). For the valence dimension, a three-way ANOVA yielded significant main effect for Direction, $F(1,19) = 8.44$, $p < .01$. Furthermore, the Condition x Stimulus x Direction interaction was significant, $F(1,19) = 2.50$, $p = .02$. Post hoc analysis revealed a significant effect of gaze direction in the live condition, $t(19) = -4.35$, $p < .001$. Direct gaze was evaluated to be less pleasant than averted gaze. The computer condition showed no effects of gaze direction ($p > .1$). Finally, no effects of direction of the control stimulus were found in either conditions (both *p*s = 1).

On the arousal dimension, a three-way ANOVA showed that all main effects were significant (Condition [$p = .005$], Stimulus [$p = .01$], and Direction [$p = .007$]). Significant interactions were obtained to Condition x Stimulus [$F(1,19) = 35.58$, $p < .001$], Condition x Direction [$F(1,19) = 13.96$, $p = .001$], and Stimulus x Direction [$F(1,19) = 10.14$, $p = .005$]. The Condition x Stimulus x Direction interaction yielded only marginally significant effect ($p = .056$). Inspection of Figure 2 suggests that the effects are due to the high arousal score in the live condition for direct gaze. Further analysis showed a significant effect for gaze direction in the live condition, $t(19) = 5.80$, $p <$

.001. The participants evaluated direct gaze in the live condition to be significantly more arousing as compared to averted gaze. On the contrary, no effect of gaze were found in the computer condition (*p* > .5). Moreover, the orientation of the control stimulus did not yield significant effects on the arousal ratings either in the live or computer conditions (both *p*s > .3).

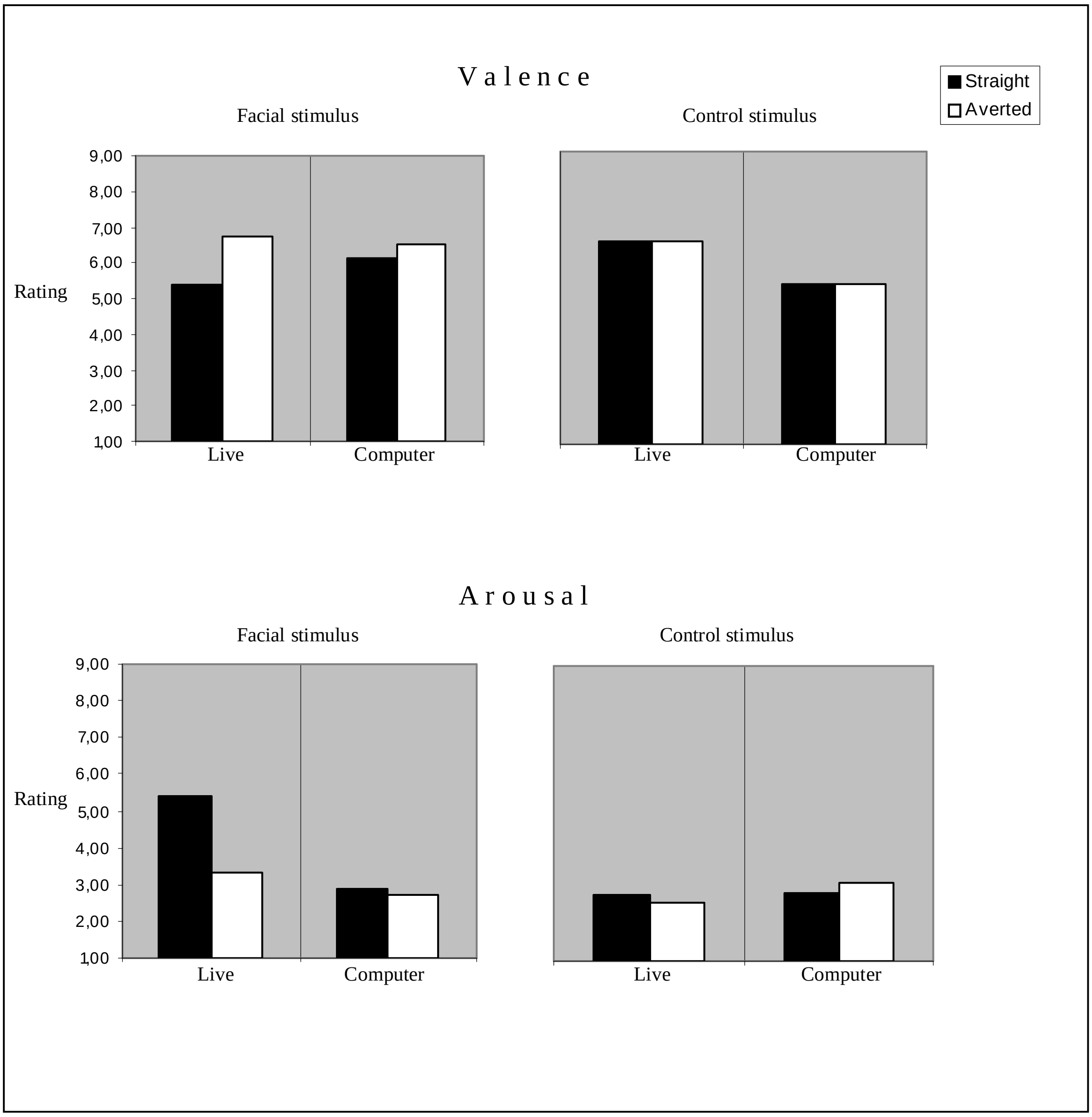

Figure 2. Mean SAM-scores of valence and arousal to each stimulus condition.
Note. Valence: 1 = very unpleasant, 9 = very pleasant. Arousal: 1 = very calm, 9 = very aroused.

4. DISCUSSION

As a social signal, direction of gaze has been shown to be associated with motivational tendencies to approach and avoid. Direct gaze has been linked to approach tendency and positive affect, whereas averted gaze has been linked to avoidance tendency and negative affect (e.g., Adams & Kleck, 2003; Adams & Kleck, 2005). At the physiological level, studies have revealed important functional differences between the left and right frontal cortex in the processing of motivational and emotional stimuli, with the left frontal cortex showing greater responses to approach-related orientation and the right frontal cortex showing greater responses to avoidance-related orientation (e.g., Coan et al., 2001; Harmon-Jones et al., 2004). EEG asymmetry has generally been investigated in the context of emotion. The present study investigated hemispheric EEG asymmetry in response to the perception of direct and averted gaze. The responses to gaze direction were examined in two different conditions of stimulus presentation: live and on a computer screen. Based on earlier results, it was expected that greater left than right frontal activation would be obtained to direct gaze and greater right than left frontal activation would be obtained to averted gaze, in accordance with approach and avoidance tendencies, respectively. Moreover, it was assumed that the responses to direct and averted gaze would be larger in the live than computer condition.

The results strongly supported the prediction, in that, greater left than right frontal activation was obtained to direct gaze and greater right than left frontal activation was obtained to averted gaze in the live condition. In other words, it seems that the perception of another person’s gaze direction does trigger distinct patterns of neural activity associated with motivational tendencies. Seeing a straight gaze evokes approach tendency because it indicates that another individual’s attention is directed at the observer and interaction is potential to happen, whereas seeing an averted gaze signals the observer that interaction with another individual is not likely to happen. Surprisingly, no effects were found in the computer condition. The pictures of faces did not produce asymmetrical effects as found in the live condition. A radio oriented straight or averted was used as a control stimulus. As expected, no effects regarding the control stimulus was obtained in either live or computer condition. Thus, the effect found here reflected an effect in response to gaze direction and not in response to a stimulus or direction per se. Overall, the data showed greater left than right-sided activation for all stimuli (facial and control stimuli regardless of direction), except for the averted gaze direction in the live condition. This is consistent with the notion of Cacioppo and

Berntson (1999) that there is, in normal healthy individuals, a weak positive or approach-oriented motivational output given to minimal or ambiguous stimuli.

Evaluations of subjective experiences revealed a significant effect of gaze direction in the live condition. Direct gaze was evaluated to be slightly less pleasant and noticeably more arousing than averted gaze. Noteworthy here, however, is that the responses still indicated a rather neutral disposition. No effects regarding the evaluations were found in the computer condition. This applied also for the control stimulus on both conditions. However, it is probably not surprising that direct gaze in the live condition was associated with lower levels of pleasantness and higher levels of arousal compared to averted gaze given the somewhat unique situation. One of the participants whose data were later excluded from the analysis even laughed whenever the stimulus face with direct gaze appeared. Surely, one might argue that even though a real individual served as a stimulus, the experimental setting was, still, rather an unusual social situation, distant from real interaction between individuals. For example, the duration of continuous gaze contact was 5 seconds, which is uncommonly long to be maintained in silence in normal interaction, with no blinks for that matter. Nevertheless, albeit from its potential peculiarity as a situation, the results strongly speak in favour for gaze direction as incentive for eliciting distinct patterns of neural activity that underlie motivational processes.

The EEG asymmetry effect for gaze direction was apparent in the live condition, but was not shown in the computer condition. This is comparable with previous studies investigating physiological arousal (measured by skin conductance, EEG, or heart rate) where stronger effects in response to direct gaze have been found when using a real-life stimulus (e.g., Gale et al., 1975) while studies with pictorial stimuli have not been able to obtain equally firm results (e.g., Donovan & Leavitt, 1980). The differences in these results exists probably because a picture of a face is lacking of social significance, it does not allow reciprocity. Baron-Cohen (1995) has presented an interesting description of the role that eye gaze may play in social cognition (i.e., the theory of mind, ToM). According to Baron-Cohen, there might be a series of dedicated modules in the human brain that have evolved to enable humans to attribute mental states to others. These modules have been suggested to be located in areas such as the amygdala, the tempo-parietal regions, including the STS, and certain areas of the frontal cortex. One of these modules, the eye-direction detector (EDD), deals specifically with gaze detection and interpretation, and plays a critical role in the development of social cognition (Baron-Cohen, 1995). In short, the EDD has three basic functions: It detects the presence of eyes or eyelike stimuli in the environment, computes the direction of gaze (e.g., direct or averted), and attributes the thoughts and intentions of another individual. The present study may be interpreted within the context of the ToM. The results here suggest that seeing a picture of a face with static eyes directed straight or averted does not actuate mechanisms of mind reading, since the EEG asymmetry effect was absent in the computer condition but was evident in the live condition. A picture of a face is probably not interpreted as being related to oneself, and thus, does not entail interpretation of the thoughts or actions of another individual. Seeing a real individual with straight or averted gaze, on the contrary, seems to actuate mechanisms of mind reading in that, it involves the interpretation of whether the other person is ready for interaction, i.e., is approachable or not.

Research on hemispheric asymmetry has mostly exploited stimuli varying in emotional content, such as film clips (Davidson et al., 1990), pictures with strong emotional content (e.g., bloody accident victims, Harmon-Jones, 2007), voluntary facial expressions (Coan et al., 2001), or even personal insult (Harmon-Jones et al., 2004). The present study demonstrates that seeing a face with direct and averted gaze without expressive information evokes asymmetrical patterns of neural activity within the frontal cortex, though, this does not apply to static pictures of faces. There has been a debate of whether the frontal hemispheric asymmetry of emotion is due to motivational direction or emotional valence. The increasing evidence that the negative emotion anger produces greater left than right frontal activation has been considered to validate the motivational direction model by some authors (Harmon-Jones & Allen, 1998; Harmon-Jones, Lueck, Fearn & Harmon-Jones, 2006; Van Honk & Schutter, 2006), since anger has an approach-oriented tendency (Fox, 1991). The present study did not attempt to address the question of whether the hemispheric asymmetry is due to motivational direction or emotional valence. Nevertheless, the results from the self-ratings in the live condition raise an interesting question. Direct gaze in the live condition was associated with lower levels of self-rated pleasantness than was the averted gaze, but showed greater left than right frontal EEG activation, whereas the opposite was true for averted gaze. Hence, the result does not seem to be compatible with the emotional valence model but seems to offer evidence for the motivational direction model. This is, however, mere speculation, since the evaluations cannot be considered to reflect an unpleasant disposition as such. Furthermore, it has been shown that EEG asymmetry in response to emotion eliciting stimuli (e.g., anger-provoking pictures) does not always correlate with self-reported emotional experience (Harmon-Jones et al., 2006).

No gender differences in relation to the hemispheric asymmetry were found. Donovan and Leavitt (1980) found only marginal arousal effects in response to pictures of faces with direct gaze, but interestingly, they found a significant effect in relation to gender with male stimulus figures eliciting stronger GSR effects than female stimulus figures. The most prominent effects were obtained when males were viewing male stimuli. The present study employed only female faces as stimuli. Hence, an intriguing question arises whether there would have been stronger effects if a male would have served as a stimulus person? Furthermore, what was the implication of the fact that the facial stimulus and the experimenter were the same person? Argyle and Williams (1969) have found that the subjective feeling of being either an observer or observed is relevant to the participants in the experimental situation. The feeling of being observed makes the situation asymmetrical and might result in evaluating the situation as uncomfortable. Argyle and Williams (1969) found that the participants felt more observed when being interviewed than when interviewing, which can be regarded as an effect of role-relationship between individuals, with the interviewer having a more dominant role. Based on this assumption, it is thus possible that the participants may have considered themselves to be more in the role of ‘the observed’ in respect to the experimenter.

One interesting issue is the effects of the EEG preparation on the results. It has been shown that the EEG preparation may have some effects on both the self-ratings and EEG asymmetry (Blackhart, Kline, Donohue, LaRowe, & Joiner, 2002). The preparation usually took 30 minutes to complete and included fitting a tight cap into the participant’s head, abrasion of the scalp with a blunt stick and application of wet electrode gel in the hair that might be somewhat unpleasant to some participants. In fact, one of the participants was forced to be excluded from the data due to his irritation and nervousness in reaction to the tight cap. Furthermore, the whole experiment lasted about two hours for each participant with the measuring equipment on all that time. It is plausible that this caused the self-ratings to be slightly shifted toward a more unpleasant and arousing direction, especially when the ratings were done in the end of the recording session. It should be noted, however, that the relation between different stimulus sets would still remain the same. Furthermore, although it is not likely that the EEG preparation had an influence on the asymmetry effect found in the present study, it is nevertheless noteworthy to consider this as a potential risk when interpreting EEG asymmetry scores, particularly in studies investigating EEG asymmetry in the context of emotion.

Several studies of hemispheric asymmetry have examined the relationship between baseline frontal cortical activity and other trait measures of emotion. It has been suggested that asymmetrical frontal cortical activity behaves like a trait, in that it demonstrates acceptable temporal consistency (Debener et al., 2000; Papousek & Schulter, 1998; Sutton & Davidson, 1997). Furthermore, frontal asymmetrical activity has been found to predict emotional responses (e.g., Tomarken et al., 1990). For example, in a recent study by Harmon-Jones (2007), the participants were exposed to pictures with different emotional content (negative, positive, neutral). The results showed no significant difference as a function of picture type, while trait anger correlated positively with relative left frontal activity in response to the anger-inducing pictures. For future studies, it would be of interest to investigate whether there exists a relationship between baseline activation and the responses to gaze direction.

In conclusion, the present study provides support for the association between perception of gaze direction and frontal hemispheric asymmetry in reflecting approach-avoidance tendencies. Furthermore, the study brings forward an important point concerning experimental designs when investigating mechanisms underlying social cognition. The effects found here were apparent only in the live condition, whereas presentation of the facial stimuli on the computer monitor demonstrated no effects. It is suggested that this is probably due to a lack of social significance conveyed by presentation of static pictures of faces.

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