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# Social communication with virtual agents: The effects of body and gaze direction on attention and emotional responding in human observers

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ABSTRACT

In social communication, the gaze direction of other persons provides important information to perceive and interpret their emotional response. Previous research investigated the influence of gaze by manipulating mutual eye contact. Therefore, gaze and body direction have been changed as a whole, resulting in only congruent gaze and body directions (averted or directed) of another person. Here, we aimed to disentangle these effects by using short animated sequences of virtual agents posing with either direct or averted body or gaze. Attention allocation by means of eye movements, facial muscle response, and emotional experience to agents of different gender and facial expressions were investigated. Eye movement data revealed longer fixation durations, i.e., a stronger allocation of attention, when gaze and body direction were not congruent with each other or when both were directed towards the observer. This suggests that direct interaction as well as incongruous signals increase the demands of attentional resources in the observer. For the facial muscle response, only the reaction of muscle *zygomaticus major* revealed an effect of body direction, expressed by stronger activity in response to happy expressions for direct compared to averted gaze when the virtual character's body was directed towards the observer. Finally, body direction also influenced the emotional experience ratings towards happy expressions. While earlier findings suggested that mutual eye contact is the main source for increased emotional responding and attentional allocation, the present results indicate that direction of the virtual agent's body and head also plays a minor but significant role.



## 1. Introduction

Gaze has been shown to be one of the major socio-communicative dimensions (Senju and Johnson, 2009). Seeing another person looking at you is likely to indicate that their attention is directed at you while averted gaze suggests that the other person's attention is directed to someone or something else. Moreover, allocating visual attention to mutual gaze seems to be the basis for the understanding of social interactions (Baron-Cohen, 1995; Tomasello and Carpenter, 2007; Tomasello et al., 2005; Velichkovsky, 1995).

In addition to the correct interpretation of gaze direction, detecting the emotional state of other persons is crucial for successful communication. Numerous studies have documented that emotional facial expressions can help to predict another person's behavioral intentions (Ekman, 1973; Fridlund, 1994; Frijda and Tcherkassof, 1997; Perrett and Emery, 1994; Russell and Fernandez-Dols, 1997). Especially basic emotions such as happiness, anger, sadness, disgust, fear and surprise are recognized above chance (e.g., Ekman, 2003; Ekman and Friesen, 1971; Izard, 1971). Furthermore, observers tend to activate similar facial muscles as those that are active in the face of the observed person (e.g., Blairy et al., 1999; Dimberg and Lundquist, 1990; Dimberg and Thunberg, 1998; Kunecke et al., 2014). The facial reactions are often incidental and covert but can be measured by electromyography (EMG). Such EMG measurements typically rely on the muscular reactions of *zygomaticus major*, which pulls the corners of the mouth up and back into a smile, and *corrugator supercilii*, which pulls the eyebrows together and down into a frown. Accordingly, *zygomaticus major* is more active in response to positive stimuli while *corrugator supercilii* is more active as a reaction to negative stimuli.

Moody et al. (2007) argue that subjects do not simply copy the perceived facial expression, but that the observed expression induces an emotion or affect, which causes a rapid facial reaction (RFR) in the observer. Similarly, Aguado et al. (2013) explain RFRs as affective reactions reflecting the valence of the stimulus. This receives further support by RFRs evoked by subliminally presented emotional stimuli (Dimberg

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et al., 2000). RFRs occur automatically as soon as 300 ms after stimulus presentation (Dimberg and Thunberg, 1998), with a peak between 500 and 1000 ms (e.g., Moody et al., 2007; Weyers et al., 2006).

Studying social interaction in nonverbal communication can be approached by employing virtual reality which allows realistic stimuli with dynamic features as well as high experimental control (Chiller-Glaus et al., 2011; Kätsyri et al., 2003). Using computer-animated agents for interaction triggers similar responses as does communication with real humans. For instance, virtual agents can transmit facial expressions as adequate as photographs depicting human actors (Spencer-Smith et al., 2001; Wehrle et al., 2000). Virtual agents can elicit differential facial muscle activity in the observer, similar to those shown in response to pictures of actual people (Mojzisch et al., 2006; Mühlberger et al., 2006; Weyers et al., 2006).

Schilbach et al. (2006) showed their participants female and male virtual agents in a functional magnetic resonance imaging (fMRI) study. In animated video sequences, virtual agents turned either towards the observer or towards an imaginary third person to the left or right. With the direct or averted turns the authors manipulated the degree of self-involvement perceived by the participants. Moreover, the virtual character displayed either socially relevant (e.g., smiling) or socially arbitrary (e.g., lip-biting) facial expressions. The fMRI signals revealed distinct and differential brain activity for the various facial expressions. Furthermore, prefrontal activation was obtained for mutual eye contact while averted gaze activated posterior-parietal regions. Mojzisch et al. (2006) used this paradigm to study fixation durations and EMG activity over *zygomaticus major*. Prolonged fixations were found when the virtual agent gazed at the participants (regardless of the facial expression) indicating increased attention due to higher self-involvement. Activity over the *zygomaticus major* was stronger when the virtual agent displayed a socially relevant facial expression as opposed to arbitrary facial movements. This effect, however, occurred independently of the gaze direction of the virtual characters.

In a further modification of the paradigm, facial expressions with different valence (happy, angry, and neutral) were used to simulate situations of potentially pleasant, unpleasant, or neutral social interactions (Schrammel et al., 2009). In addition to the registration of eye movements and EMG, emotional experience as perceived by the observer was obtained via the Self-Assessment-Manikin (SAM; Lang, 1980) to reveal whether RFRs were merely mimicking behavior or actual affective responses. Longer fixations in response to angry and neutral faces compared to happy faces were interpreted as increased attention allocation to potential threat cues in social communication. EMG activity as well as self-reported emotional experience differentiated more clearly between the characters' happy and angry expression in case of mutual eye-to-eye contact. Accordingly, RFRs seem to be part of an emotional reaction.

Although the eyes reliably indicate the direction of a person's attention, in an ever-changing natural world, the eyes are hardly the only source of information about others' direction of attention. In the studies discussed above (Mojzisch et al., 2006; Schilbach et al., 2005; Schrammel et al., 2009), body and gaze direction were always matched. Therefore, the magnitude of the respective contribution of body and gaze direction on the described effects could not be determined. For instance, it remained open whether the prolongation of fixations is the same in case of direct gaze but averted body. Different forms of interrelation between gaze and body direction are conceivable. For instance, both forms of direction contribute to the obtained measures with the same amount, i.e., in an additive fashion. Alternatively, gaze direction could also be independent of the body direction. Therefore, differentiating between body and gaze direction seems relevant to attribute and understand the described effects correctly.

Several studies reported that estimation of gaze direction is not always straightforward and might be influenced by body orientation. For example, subjects misjudge gaze direction when gaze and body direction are incongruent (Cline, 1967; Gibson and Pick, 1963). Kluttz et al. (2009) found less precise estimation of gaze direction for direct gaze and averted body compared to direct gaze and body; body direction was irrelevant for averted gaze. Conty et al. (2007) reported shortest reaction times for direct gaze and body, reaction times were slowest for averted gaze and body. Similar findings indicated the influence of several components of the event-related potentials (ERP). For the N170, P3a and P3b components, activations were largest for direct gaze and body and smallest for averted gaze and body. Taken together, the perception of gaze direction seems to be influenced by the overall configuration of gaze and body posture. In particular, incongruence between gaze and body direction seems to impair the correct identification of gaze direction and thereby complicates the assessment of self-relevance in social situations. It is unclear however, how incongruent body and gaze direction affects allocation of attention, and emotional response.

In the present study, we aimed to disentangle the effects of gaze direction from body orientation in order to clarify their respective influence on visual attention, RFRs and emotional experience. Therefore, similar stimuli as in the study by Schrammel et al. (2009) were used, including body orientation as additional factor. Body orientation could be direct or averted and therefore be congruent or incongruent with the gaze direction. Furthermore, the virtual agents displayed happy, angry or neutral facial expressions. We examined (1) fixation duration as a measure of visual attention, (2) RFRs as indicated by facial EMG (i.e., *zygomaticus major* and *corrugator supercilii*) and (3) subjective emotional experience obtained by SAM-Ratings. Based on earlier findings, we expected longest fixations, strongest RFRs and emotional experience for direct body and gaze. We expected shortest fixations, weakest RFRs and emotional experience for averted body and gaze. Since body direction might influence perception and experience of gaze direction, we furthermore anticipated prolonged fixations for both incongruent body and gaze configurations. However, we expected RFRs and emotional experience to be attenuated for incongruent conditions.

## 2. Methods

### 2.1. Subjects

Forty subjects (20 females) with a mean age of 23.4 ± 3.6 years (females: 22.1 ± 2; males: 24.3 ± 4.33) were recruited at the Technische Universitaet Dresden. Subjects gave informed consent for their participation and were kept naïve in terms of the study's purpose. All subjects had normal or corrected-to-normal vision and received either course credit or €5 per hour in compensation for their participation. The study was conducted in conformity with the declaration of Helsinki and approved by the Ethics Committee of the Technische Universitaet Dresden.

### 2.2. Apparatus

*Eye movements* were recorded binocular using the SR Research Ltd. EyeLink 1000 eye-tracking system (SR Research, Ontario, Canada) with a spatial resolution below 0.01° and a spatial accuracy of better than 0.5°. Head movements were restrained by a chin and forehead rest and the system was operated with a sample rate of 500 Hz. Saccades and fixations were defined using the saccade detection algorithm supplied by SR Research: Saccades were identified by deflections in eye position in excess of 0.1°, with a minimum velocity of 30°s − 1 and a minimum acceleration of $8000°s^{-2}$, maintained for at least 4 ms.

*Facial EMG* was measured bipolar over the regions of the *zygomaticus major* and the *corrugator supercilii* on the left side of the face according to the guidelines of Fridlund and Cacioppo (1986). A reference electrode was attached to the right earlobe and a grounding electrode was attached to the left earlobe. We used Ag–AgCl miniature surface electrodes filled with electrode paste. Before attachment, the skin was cleansed with alcohol and electrode paste. EMG activity was recorded