Influences of spontaneous perspective taking on spatial and identity processing of faces

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Previous research suggests that people, when interacting with another agent, are sensitive to the other's visual perspective on the scene. The present study investigated how spontaneously another's different spatial perspective is taken into account and how this affects the processing of jointly attended stimuli. Participants viewed upright or inverted faces alone, next to another person (same spatial perspective), or opposite another person (different spatial perspectives) while electroencephalography (EEG) was recorded. The task (counting male faces) was in no way related to spatial aspects of the stimuli, and thus did not encourage perspective taking. EEG results revealed no general differences between viewing faces alone or with another person. However, when holding different perspectives (sitting opposite each other), the amplitudes of the N170 and of the N250 significantly increased for upright faces. This indicates that people spontaneously represented the other's different perspective, which led to higher demands for structural encoding (N170) and to increased allocation of attention to face recognition (N250) for stimuli that are typically processed configurally. When holding different spatial perspectives, thus, people may not merely represent that the other sees the object or scene differently, but how the object/scene looks for the other.

INTRODUCTION

Successful social interactions often require that situations are judged from the viewpoint of someone else. To understand why a teacher and a pupil have opposing opinions about a day-trip to the sea instead of to a museum, for instance, it is essential to realize what the events mean to either of them. Remarkably, everyday language often refers to these abilities in visuospatial terms. 'Seeing it from their perspective' or 'putting oneself in the shoes of' are examples of phrases used to describe the ability to represent an event as it might be perceived or judged by someone else.

Recent studies have shown that humans take the spatial perspective of those they observe and those they interact with into account (Belopolsky et al., 2008; Thirioux et al., 2009). When jointly attending to scenes or objects, people are sensitive to their co-attendees' perspectives. Samson et al. (2010), for example, asked participants to judge the number of discs presented on the walls of a virtual room. An avatar was presented in the scene and was positioned in a way that it could either 'see' the same number of discs as participants or a different number of discs. Even though the avatar was irrelevant to the task, its spatial relation towards the discs influenced participants' performance. When classifying how many discs they perceived themselves, the participants reacted faster when the avatar could see the same number of discs than when it perceived a different amount of discs. This result illustrates that participants were influenced by what the avatar could and could not see. Data from a subsequent electroencephalography (EEG) study employing a similar experimental setup suggest that calculating and representing one's own and the other's perspective takes place ~450 ms after stimulus onset in the parietal cortex while selecting the appropriate (e.g. one's own) perspective requires executive control and is reflected in a later frontal component (McCleery et al., 2011).

Several studies where spatial relations had to be judged or described revealed that participants took the visuospatial perspectives of observed humans (Frischen et al., 2009), pictures of humans (Tversky and Hard, 2009; Zwickel and Müller, 2010) and even of triangles depicting intentional movement patterns (Zwickel, 2009) into account. The influence of a co-actor's spatial position thereby is modulated by whether it leads to actual perceptual differences between actors (Böckler et al., 2011). When pairs of participants sat opposite each other and performed a mental rotation task on pictures shown on a flat screen, participants' performance-rotation curves were flattened when the person opposite was attending to the stimuli as compared to when her eyes were closed. Thus, another person's different perspective affects people's performance especially when it is relevant to the other, that is, when the other has open eyes and actively attends to the scene.

Taken together, research on perspective taking has shown that people consider each other's spatial perspectives and that this affects subsequent task performance. With the present study, we set out to extend previous research in two ways. First, it is currently unknown how spontaneously perspective taking occurs. Tasks in previous studies have highlighted differences in percepts of the two attendees, explicitly demanded perspective judgements (Samson et al., 2010), entailed spatial judgements (Tversky and Hard, 2009) or asked for spatial processing of objects that had different spatial relations towards the participant and the other person (mental rotation, Böckler et al., 2011; left/right judgements, Zwickel, 2009, Zwickel and Müller, 2010). We investigated whether people engage in perspective taking even when the task does not require processing of spatial relations.

Second, it has not been studied until now how a co-actor's different spatial perspective affects the processing of jointly attended objects. The EEG study by McCleery et al. (2011) revealed the time-course of representing different perspectives and selecting the appropriate perspective when a scene had to be explicitly judged from one's own or another person's point of view. It is still unknown, however, where in the course of stimulus processing spontaneous perspective taking exerts its influence. Does the different perspective of a co-actor affect how people attend to, perceive and/or cognitively process their own stimuli? The present experiment addresses how a co-actor's perspective affects processing of jointly attended objects.

In the present experiment, pairs of participants looked at a computer screen that was placed flat on a table, with the monitor facing the ceiling. Participants performed a task that was independent of spatial processing, namely counting how many of the depicted faces in a given experimental block were male. The position of the co-actor (performing the exact same task) was varied during the experiment. S/he could either hold the same perspective on stimuli as the participant (sitting next to the participant) or the opposite spatial perspective (facing the participant and therefore having a different view on stimuli).

Face stimuli were used because people can recognize faces rapidly and accurately (Bruce and Young, 1998) and because face processing differs for upright and inverted faces already at an early stage (Farah et al., 1995; Chambon et al., 2006). While upright faces were proposed to be processed by analysis of their configuration (this is, holistically), inverted faces were suggested to be initially processed using first-order relational information (that is, locally, or feature based; Williams et al., 2004). This orientation-specific processing allows testing whether and how the processing of upright and inverted faces is affected by a co-actor's different spatial perspective. In contrast, the task itself (counting male faces) was not related to the spatial orientation of the faces. If the co-actor's perspective is spontaneously represented, orientation-specific face processing should be different when the co-actor holds the opposite view on face stimuli than when s/he holds the same view. To control for general effects of attending jointly (independent of spatial positions), we included an individual baseline condition in which participants attended to the faces alone.

The precise temporal nature of effects of a co-actor's (different) spatial perspective was investigated by means of EEG. There are some well-established event-related potentials (ERPs) reflecting configural processing and recognition of faces (e.g., Rossion et al., 1999; Schweinberger et al., 2004; Sadeh and Yovel, 2010; Pesciarelli et al., 2011) that can be analyzed as indicators of how faces of different orientations are processed.

The P1 is a positive deflection on parietal and occipital sites peaking around 100 ms after stimulus onset. The amplitude of the P1 is increased for inverted faces as compared to upright faces (Halit et al., 2000; Itier and Taylor, 2002, 2004) and was suggested to reflect early attentional and holistic processing. If a co-actor's spatial perspective is spontaneously represented and affects face processing as early as 100 ms after stimulus onset, a modulation of the P1 effect should be revealed when participants sit opposite each other.

A well-studied component in the face processing literature is the N170, a negative deflection on posterior occipitotemporal sites especially on the right hemisphere (electrode site PO8) that has been suggested to reflect structural encoding in the perceptual analysis of faces (i.e. detection of facial patterns), but to be unrelated to face recognition (Bentin and Deouell, 2000; Eimer, 2000a,b). The N170 is typically larger and delayed in latency for inverted (as compared with upright) faces which are thought to be more difficult to encode into a holistic representation (Rossion et al., 1999). If participants represent the depicted face not only from their own but also from the other's perspective faces should be processed differently depending on the other's perspective. Specifically, when the co-actor sits opposite to the participant, upright faces (as seen from the perspective of the participant) would be interfered with the co-represented inverted faces (as seen by the co-actor). Upright faces are usually processed holistically, but the co-representation of the other's perspective would disrupt configural processing (as the other sees the face upside down). This should lead to an increased N170 for upright faces when the other person holds the opposite view as compared with when the other holds the same view.

The N250, a negative deflection over posterior temporal sites especially on the right hemisphere, has been suggested to be related to individual face recognition (Begleiter et al., 1995; Schweinberger et al., 1995; Pfütze et al., 2002). Typically, the N250 is measured across trials in which face stimuli are repeated and increases when the same upright face is shown repetitively (N250r, see Schweinberger et al., 2002a, 2004). Most likely, the N250 reflects activation of facial representations for recognition. Thus, if a co-actor's different perspective affects how participants represent a given face, for example how active the representation is for recognition the N250 should be modulated by where the co-actor is positioned.

If the mere presence of a co-actor affects face processing (independent of the co-actor's spatial position), components related to attention allocation and face processing should be modulated whenever a co-actor is present. For instance, if the allocation of attention is enhanced by a co-attendee this might be reflected in an increase of the P1. Similarly, if the presence of another person affects configural or identity processing this should be reflected in general effects of another person's presence in the N170 and N250, respectively.

METHODS

Participants

Sixteen students (mean age 24 years; 8 females; all right handed) participated in the experiment and received course credits for participation. All of them reported normal or corrected-to-normal vision and signed informed consent prior to the experiment.

Stimuli and procedure

Participants viewed a 17-in TFT monitor that was placed flat on a table and pointed towards the ceiling. The viewing distance was 50 cm. Ambient light was kept at a constant level.

Stimuli consisted of three female and three male faces ($13.7 \times 21.5°$ visual angle) taken from the Karolinska face data base (Lundqvist et al., 1998).

Each trial started with the presentation of a fixation cross (size $0.8°$ visual angle, presented in the centre of the screen) for 700 ms. Subsequently, one of the six faces appeared on the screen either upright or inverted for 600 ms. Faces and orientations of faces were randomized within blocks. Finally, the screen stayed blank for another 700–1000 ms (randomized inter stimulus interval). Participants were asked to count male faces depicted in each block, independent of orientation. Blocks could either consist of 36 trials (18 male faces), 48 trials (24 male faces), or 60 trials, (30 male faces), while block length was unknown to participants. After each block, participants noted how many male faces they have counted.

A practice block was followed by 12 experimental blocks. The experiment consisted of three parts: participants attended and performed the task alone, participants sat next to a confederate who performed the same task or participants sat opposite the confederate performing the same task. Each part consisted of 4 blocks (one block, a 36 trials; two blocks, a 48 trials and one block, a 60 trials). The order of blocks within parts was counterbalanced across participants. The order of parts within the experiment was balanced in such a way that one half of the participants started performing the task alone and the other half started performing the task with a confederate (either sitting next or opposite participants). This sequence was chosen to control for order effects reported in previous literature, namely that performing a task alone subsequent to performing it jointly differs from performing a task alone to start with (Atmaca et al., 2011; Vesper et al., 2011).

Psychophysiological recordings and data analysis

The EEG of each participant was recorded continuously from 29 Ag/AgCl electrodes (FP1, FP2, F3, F4, FC1, FC2, FC3, FC4, C3, C4, T7, T8,

P3, P4, P7, P8, PO3, PO4, PO7, PO8, O1, O2, Fz, FCz, Cz, CPz, Pz, POz and Oz). AFz served as ground electrode. All electrodes were referenced online to a right mastoid electrode. Vertical electro-ocular (vEOG) and horizontal EOG (hEOG) activity were recorded above and below the left eye and from the left and right outer canthi, respectively.

Electrode impedance was kept below $10 k\Omega$. EEG and EOG were filtered online using a 70 Hz low pass filter and a time constant of 15 s. All EEG signals were digitized with a sample frequency of 500 Hz. Trials containing blinks were corrected offline utilizing the Brain Vision Analyzer. Remaining artefacts were eliminated semi-automatically according to visual inspection. Trials with hEOG or vEOG activity exceeding a range of $25 \mu V$ during the epoch were discarded from all analyses. Offline data were referenced to the averaged activity of both mastoids. The EEG epochs were then averaged separately for each participant and experimental condition and aligned to a 200 ms baseline preceding stimulus onset. Subsequent to artefact correction, an average of 86 trials per condition per participant was included in the analyses (minimum 66 trials per condition per participant).

P1 amplitudes were analyzed at parietal and occipital electrodes (Oz, POz, O1, O2, PO3 and PO4). Amplitudes (mean activity) were analyzed in the time range from 70 to 110 ms.

Based on the existing literature, the N170 was analyzed at PO7 and PO8. Amplitudes (mean activity) were analyzed in the time range from 140 to 170 ms.

The N250 was analyzed at PO7 and PO8. Amplitudes (mean activity) were analyzed in the time range from 250 to 310 ms.

Data analysis

A repeated measures analysis of variance (ANOVA) was performed on accuracy (counting errors per block) including the variable co-actor condition (attending alone *vs.* attending next to confederate *vs.* attending opposite confederate). Additionally, we tested whether the amount of errors decreased over time. To this end, we carried out an ANOVA on the variable part of experiment (first part *vs.* second part *vs.* third part). ERP measures were analyzed by means of repeated measures ANOVAs including the variables face orientation (upright *vs.* inverted), co-actor condition (attending alone *vs.* attending next to confederate *vs.* attending opposite confederate) and hemisphere [N170 and N250: PO7 *vs.* PO8; P1: left hemisphere (PO3, O1) *vs.* midlines (POz, Oz) *vs.* right hemisphere (PO4, O2)]. Huynh–Feldt corrections (Huynh and Feldt, 1976) were applied if necessary. Planned single comparisons were performed by means of two-tailed *t* tests.

Debriefing

Subsequent to the experiment, participants were debriefed. All participants were asked whether they had noticed that only three different block lengths were used (implying that only three possible numbers of male pictures were shown). Second, we inquired what participants thought the experiment was about.

RESULTS
Behavioral results

As expected, the amount of counting errors per block did not depend on co-actor condition [$F(1, 15) < 1$] (Table 1). Also, errors did not significantly decrease or increase over parts of the experiment [$F(1, 15) < 1$]. This suggests that participants were not aware that only three different amounts of male faces were shown throughout the experiment.

Table 1 Mean errors (in %) and standard deviation of errors for the three different seating conditions (alone, next and opposite)

Spatial position/seating condition	Mean errors (%)	SD (%)
Alone	1.8	1.6
Next (same perspective)	1.5	1.4
Opposite (different perspective)	1.8	1.4

Debriefing

None of the participants noticed that only three different block lengths had been employed throughout the experiment. Furthermore, participants were not aware of the purpose of our manipulations. When asked about the rationale behind this study five of the participants assumed that the change in position of the co-actor was intended to induce cooperation or competition.

Electrophysiological results

P1: In line with previous literature, P1 amplitudes were significantly larger for inverted as compared with upright faces [$F(1, 15) = 5.8$, $P < 0.05$]. The inversion effect significantly interacted with hemisphere [$F(2, 30) = 4.2$, $P < 0.05$], as it was only significant at midline and right electrodes Oz, O2, POz and PO4 [$F(1, 15) \geq 6.4$, $P < 0.05$] (Figure 1). No other factor or interaction approached significance [$F(1, 15) \leq 1.4$, $P > 0.25$]

N170: No main effect of co-actor condition and hemisphere was revealed [$F(2, 30) < 1$]. Amplitudes differed marginally depending on face orientation [$F(1, 15) = 3.9$, $P < 0.07$]. A significant two-way interaction of face orientation and co-actor condition was found at PO8 [$F(2, 30) = 3.4$, $P < 0.05$]. This was due to a significantly more negative amplitude for upright faces when the confederate attended from the opposite position [$t(15) = 3.1$, $P < 0.01$], whereas no effect of face orientation was found in the other co-actor conditions [$t(1, 15) \leq 1.3$, $P > 0.19$] (Figure 2). This interaction was not present at PO7 [$F(2, 30) < 1$], reflected in a significant three-way interaction of hemisphere, face orientation and co-actor condition [$F(2, 30) = 3.4$, $P < 0.05$].

To gain a better understanding of the absence of the typical N170 inversion effect (larger amplitudes for inverted faces) in the 'attending alone' condition, we performed an additional analysis including the factor starting condition (starting the task by attending alone *vs.* starting by attending jointly). As previous literature reported order effects in joint action experiments (Atmaca *et al.*, 2011; Vesper *et al.*, 2011), we aimed at investigating whether the condition with which participants began modulated the N170 inversion effect.

Results revealed that starting condition interacted marginally with the inversion effect in the 'attending alone' condition [$F(1, 15) = 3.5$, $P < 0.09$], as the typical N170 inversion effect was numerically present when participants started alone [$t(15) < 1$] but was inverted (numerically) when they started jointly [$t(15) = 1.9$, $P = 0.11$]. No such order effects were found in the 'attending next' and 'attending opposite' condition [$F(1, 15) < 1$]. Additionally, when data of participants who started alone were analyzed separately ($n = 8$) including the factors face orientation and co-actor condition, the two-way interaction was significant [$F(1, 7) = 4.6$, $P < 0.05$], depicting the same effect as the overall sample (increase of amplitude for upright faces when co-actor sits opposite).

N250: Co-actor condition did not affect the amplitude of the N250 [$F(2, 30) = 1$]. No main effect of face orientation was found [$F(1, 15) = 2.8$, $P < 0.12$]. A significant two-way interaction of face
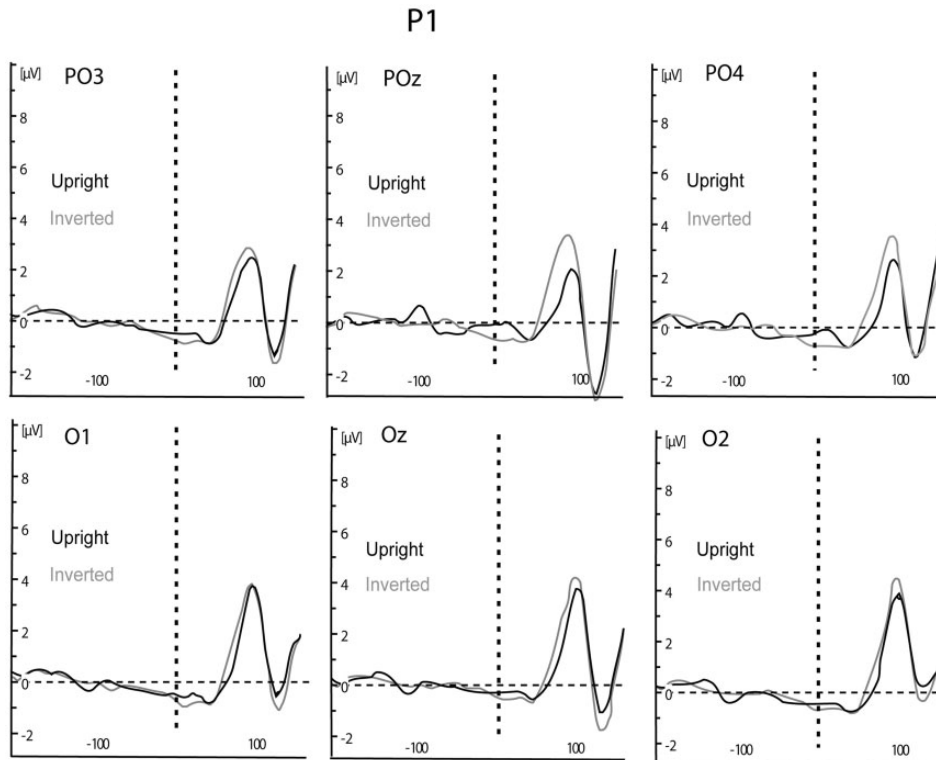
P1

Fig. 1 Mean voltages for upright (black) and inverted (grey) faces in the P1 time range at electrode sites PO3, POz, PO4, O1, Oz and O2.
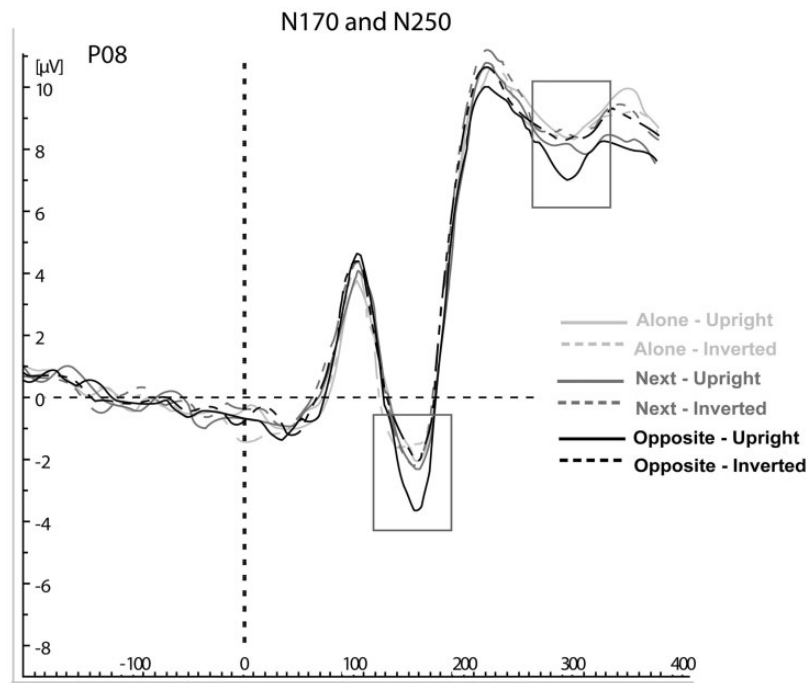
N170 and N250

Fig. 2 Mean voltages for all stimulus conditions (alone—upright: light grey, straight line; alone—inverted: light grey, dashed line; next—upright: dark grey, straight line; next—inverted: dark grey, dashed line; opposite—upright: black, straight line; opposite—inverted: black, dashed line) at electrode site PO8 in the N170 and N250 time range (effects highlighted in grey box).

orientation and co-actor condition was revealed at PO8 [$F(2, 30) = 3.6$, $P < 0.05$], due to a significantly larger negative amplitude for upright faces when the confederate attended from the opposite position [$t(15) = 2.4$, $P < 0.05$], whereas no effect of face orientation was found when the other sat next to the participant or when the participant attended alone [$t(15) < 1$] (Figure 3). Finally, we found a significant three-way interaction of face orientation, co-actor condition and hemisphere [$F(2, 30) = 4.1$, $P < 0.05$], because the two-way

interaction of face orientation and co-actor condition was significant at PO8 but did not reach significance at PO7, [$F(2, 30) < 1$].

In an additional analysis, we examined whether the increase in amplitude for upright faces when the co-actor was sitting opposite participants was correlated for the N170 and the N250 at PO8. Indeed, the Pearson Correlation revealed a significant positive correlation between this effect in both time ranges ($r = 0.57$, $P = 0.016$). Thus, the larger the N170 amplitude difference was between upright and inverted faces when the co-actor attended from the opposite side (as compared to when participants attended alone or next to each other), the larger the same amplitude difference was in the N250 time range.

DISCUSSION

The present study investigated whether a co-actor's different spatial perspective is spontaneously taken into account and affects the processing of jointly attended faces. Contrary to previous studies, the task at hand did not require processing of spatial relations. Accordingly, participants' task performance was not affected by the presence or the spatial perspective of the co-actor. This finding, however, should be treated cautiously since counting was only a cover task and might have been too coarse a measure for detecting modulations.

ERP results revealed no general effects of another attendee, suggesting that the mere presence of another actor did not modulate attention allocation, spatial face processing and face recognition in the experiment at hand.

In contrast, structural encoding and recognition processing of faces both were influenced by the co-actor's spatial perspective. When the co-actor sat opposite participants the N170 on the right hemisphere was enhanced for upright faces as compared with when the other sat next to the participant or when the participant attended alone. This finding points towards a higher demand for configural processing of upright faces when they were viewed from different spatial perspectives and suggests that the other's (opposite) perspective was spontaneously represented. When the co-actor attended from the opposite perspective, upright faces were interfered with the co-represented inverted faces (as seen by the co-actor). Representing the other's perspective may have led to a somewhat 'chimerical' representation of the jointly attended face and disrupted holistic processing or induced a conflict as to whether the face should be processed in a holistic or a local manner. Why was there no effect of the co-actor's perspective when faces were inverted? Considering that it might be impossible to process inverted faces in a holistic manner to start with, the representation of a co-actor's perspective likely could not change the processing of inverted faces from local to holistic. Inverted faces, thus, may have been 'immune' to inducing conflicted or chimerical representations.

It has been argued that different neurons respond to eyes and to faces, and that eye-sensitive neurons are inhibited when upright faces are shown (Itier et al., 2004, 2006, 2007). In inverted faces (which are not processed holistically), in contrast, both face and eye-sensitive neurons respond, thereby increasing the N170 amplitude (Itier et al., 2004, 2006, 2007). When viewing upright faces while the co-actor held the opposite perspective, participants in this study may have held a feature-based (local) co-representation of the face, which allowed overcoming the inhibition of eye-sensitive neurons and increased the amplitude of the N170.

Somewhat surprisingly, no general face inversion effect was detected in the N170 range when participants attended alone or next to each other. Subsequent analyzes indicate that whether participants started by attending alone or together with another person affected the size of the N170 effect. Participants who started out attending alone depicted the typical N170 inversion pattern, whereas participants who began by attending together did not. When starting out by attending from opposite positions people seem to not fully recover their view on faces when attending alone. This is in line with previously reported order effects in the joint action literature (see Atmaca et al., 2001; Vesper et al., 2011). It has to be noted, though, that the order effect was only marginally significant and further research is necessary to draw stronger conclusions. Importantly, participants who started by attending alone showed the same modulation of the inversion effect by the different perspective of the co-actor as did the complete sample, suggesting that all participants took their co-actors perspective into account when jointly attending to face stimuli.

The N250 amplitude on the right hemisphere was larger for upright faces when participants sat opposite each other as compared to when they attended from the same perspective or alone. The N250 component is related face recognition, more specifically, to the activation of face representations to recognize faces (Schweinberger et al., 2004). Holding a representation not only of their own but also of the other's view on face stimuli (inducing a 'chimerical' face image in the N170 time range) participants may have needed more resources to overcome this chimerical representation. In turn, this may have led to enhanced activation of face representations in the time course of face recognition (N250). Supporting the above interpretation, the influence of the co-actor's perspective on upright faces was correlated for the N170 and the N250 time range. This suggests that the more the initial representation of the face was affected by a co-actor's different perspective (the larger the N170 for upright faces in the opposite condition as compared with all other co-actor conditions) the larger the subsequent effect was on face recognition. When the co-actor's perspective was represented and the resulting chimerical representation of the face rendered configural processing more demanding (N170), more attentional resources were attributed to the recognition of this face (N250).

Note that in classic repetition experiments, the N250r for repeated face pictures is typically decreased for inverted faces as compared with upright faces (Schweinberger et al., 2004). The present study did not employ a repetition paradigm and results did not reveal general inversion effects in the N250. Importantly, the above interpretation of the N250 results is not based on the assumption of general differences between processes involved in the recognition of upright and inverted faces, which are accessed in repetition paradigms. However, more research is certainly needed to clarify the functional significance of the N250 in itself and in relation to the N170.

No effect of the other's perspective was revealed in the P1 component, implying that attentional processing and early configural processing of the stimulus at 100 ms following its onset were not affected by the co-actor's perspective. The presence of an overall inversion effect on the P1 amplitude suggests that the inversion of face stimuli exerts an influence prior to the effect of the co-actor's perspective.

Taken together, our results extend the perspective taking literature in two ways. They show that a co-actor's spatial perspective is considered spontaneously. Even though the present task could be solved without processing spatial relations or perform perspective transformations people spontaneously represented their co-actors' perspectives. Furthermore, perspective taking affected early configural processing of the jointly attended stimuli ∼150 ms following stimulus onset as well as processes of face recognition ∼250 ms following stimulus onset. This adds to the findings of later posterior and frontal components involved in perspective judgments and the selection of the appropriate perspective (McCleery et al., 2011).

Present findings have implications for how perspective taking can be understood. Are objects and scenes represented as if seen from the perspective of someone else, or do non-spatial high-level representations of the co-actor's perspective affect performance? In the study by Samson et al. (2010), for instance, participants could have represented

the discs as if seen by the avatar, for instance, perform a mental perspective transformation. Alternatively, participants could have represented the fact that the avatar sees three discs in rather high-level propositions, e.g. SEE(AVATAR, 3 discs). The latter does not involve spatial concepts *per se*. We found that spatial perspective taking is spontaneous and affects how stimuli are *perceptually* processed. Perspective taking, hence, seems to be a rather effortless, automatic process that affects how people perceive, spatially process and recognize the jointly attended object. This points towards the first view on perspective taking as representing not only *that* a co-actor sees a jointly attended scene differently, but also *how* the other perceives it.

Our perception of the world seems to be influenced by the perception of those we interact with. Taking the spatial perspectives of our co-actors into account may help coordinating our actions with them and underlie inferring what they have in mind by establishing a perceptual common ground (Clark, 1996; Sebanz *et al.*, 2006; Knoblich *et al.*, 2011). Coming back to our initial example, a common ground may provide the basis on which a teacher can understand her pupils' mental perspectives regarding a trip to a museum.

REFERENCES

Atmaca, S., Sebanz, N., Knoblich, G. (2011). The joint flanker effect: sharing tasks with real and imagined co-actors. *Experimental Brain Research*, 211, 371–85.

Belopolsky, A.V., Olivers, C.N.L., Theeuwes, J. (2008). To point a finger: attentional and motor consequences of observing pointing movements. *Acta Psychologica*, 128(1), 56–62.

Begleiter, H., Porjesz, B., Wang, W. (1995). Event-related brain potentials differentiate priming and recognition to familiar and unfamiliar faces. *Electroencephalography Clinical Neurophysiology*, 94, 41–9.

Bentin, S., Deouell, L.Y. (2000). Structural encoding and identification in face processing: ERP evidence for separate mechanisms. *Cognitive Neuropsychology*, 17, 35–54.

Böckler, A., Knoblich, G., Sebanz, N. (2011). Giving a helping hand: effects of joint attention on mental rotation of body parts. *Experimental Brain Research*, 211, 531–45.

Bruce, V., Young, A.W. (1998). *In the Eye of the Beholder: The Science of Face Perception*. Oxford: Oxford University Press.

Chambon, V., Baudouin, J.Y., Franck, N. (2006). The role of configural information in facial emotion recognition in schizophrenia. *Neuropsychologia*, 44, 2437–44.

Clark, H. (1996). *Using Language*. Cambridge: Cambridge University Press.

Eimer, M. (2000a). Event-related brain potentials distinguish processing stages involved in face perception and recognition. *Clinical Neurophysiology*, 111, 694–705.

Eimer, M. (2000b). The face-specific N170 component reflects late stages in the structural encoding of faces. *NeuroReport*, 11, 2319–24.

Farah, M.J., Drain, H.M., Tanaka, J.W. (1995). What causes the inversion effect? *Journal of Experimental Psychology: Human Perception & Performance*, 21, 628–34.

Frischen, A., Loach, D., Tipper, S.P. (2009). Seeing the world through another person's eyes: simulating selective attention via action observation. *Cognition*, 111(2), 212–8.

Halit, H., de Haan, M., Johnson, M.H. (2000). Modulation of event-related potentials by prototypical and atypical faces. *Neuroreport*, 11, 1871–5.

Huynh, H., Feldt, L.S. (1976). Estimation of the box correction for degrees of freedom from sample data in the randomized block and split-plot designs. *Journal of Educational Statistics*, 1, 69–82.

Itier, R.J., Latinus, M., Taylor, M. (2006). Face, eyes and object early processing: what is the face specificity? *Neuroimage*, 29, 667–76.

Itier, R.J., Taylor, M.J. (2002). Inversion and contrast reversal affect both encoding and recognition of faces: a repetition study using ERPs. *Neuroimage*, 15, 353–72.

Itier, R.J., Taylor, M.J. (2004). N170 or N1? Spatiotemporal differences between object and face processing using ERPs. *Cerebral Cortex*, 14(2), 1815–26.

Itier, R.J., Alain, C., Sedore, K., McIntosh, A. (2007). Early face processing specificity: It's in the eyes!. *Journal of Cognitive Neuroscience*, 19(11), 132–142.

Knoblich, G., Butterfill, S., Sebanz, N. (2011). Psychological research on joint action: theory and data. In: Ross, B., editor. *The Psychology of Learning and Motivation*, Vol. 54, Burlington: Academic Press, pp. 59–101.

Lundqvist, D., Flykt, A., Öhman, A. (1998). The Karolinska directed emotional faces [Database of standardized facial images]. Available from Psychology Section, Department of Clinical Neuroscience, Karolinska Hospital, Stockholm, Sweden.

McCleery, J.P., Surtees, A.D.R., Graham, K.A., Richards, J.E., Apperly, I.A. (2011). The neural and cognitive time course of theory of mind. *The Journal of Neuroscience*, 31(36), 12849–54.

Pesciarelli, F., Sarlo, M., Leo, I. (2011). The time course of implicit processing of facial features: an event-related potential study. *Neuropsychologia*, 49(5), 1154–61.

Pfütze, E.-M., Sommer, W., Schweinberger, S.R. (2002). Age-related slowing in face and name recognition: evidence from event-related brain and associative priming of face recognition: evidence from event-related brain-potentials. *Psychology and Aging*, 17, 140–60.

Rossion, B., Delvenne, J.F., Debatisse, D., et al. (1999). Spatio-temporal localization of the face inversion effect: an event-related potentials study. *Biological Psychology*, 50(3), 173–89.

Sadeh, B., Yovel, G. (2010). Why is the n170 enhanced for inverted faces? An erp competition experiment. *Neuroimage*, 53(2), 782–9.

Samson, D., Apperly, I.A., Braithwaite, J.J., Andrews, B.J., Scott, S.E.B. (2010). Seeing it their way: evidence for rapid and involuntary computation of what other people see. *Journal of Experimental Psychology: Human Perception and Performance*, 36(5), 1255–66.

Schweinberger, S.R., Pfütze, E.-M., Sommer, W. (1995). Repetition priming and associative priming of face recognition: evidence from event-related potentials. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21, 722–36.

Schweinberger, S.R., Pickering, E.C., Jentzsch, I., Burton, A.M., Kaufmann, J.M. (2002a). Event-related brain potential evidence for a response of inferior temporal cortex to familiar face repetitions. *Cognitive Brain Research*, 14, 398–409.

Schweinberger, S.R., Huddy, V., Burton, M. (2004). N250r: a face-selective brain response to stimulus repetitions. *NeuroReport*, 15, 1501–4.

Sebanz, N., Bekkering, H., Knoblich, G. (2006). Joint action: bodies and minds moving together. *Trends in Cognitive Sciences*, 10, 70–6.

Thirioux, B., Jorland, G., Bret, M., Tramus, M.-H., Berthoz, A. (2009). Walking on a line: a motor paradigm using rotation and reflection symmetry to study mental body transformations. *Brain and Cognition*, 70(2), 191–200.

Tversky, B., Hard, B.M. (2009). Embodied and disembodied cognition: spatial perspective-taking. *Cognition*, 110(1), 124–9.

Vesper, C., van der Wel, R.P.R.D., Knoblich, G., Sebanz, N. (2011). Making oneself predictable: reduced temporal variability facilitates joint action coordination. *Experimental Brain Research*, 211, 517–30.

Williams, M.A., Moss, S.A., Bradshaw, J.L. (2004). A unique look at face processing: the impact of masked faces on the processing of facial features. *Cognition*, 91, 155–72.

Zwickel, J. (2009). Agency attribution and visuospatial perspective taking. *Psychonomic Bulletin & Review*, 16(6), 1089–93.

Zwickel, J., Müller, H.J. (2010). Observing fearful faces leads to visuo-spatial perspective taking. *Cognition*, 117(1), 101–5.