Journal of Experimental Psychology:
Human Perception and Performance
2017, Vol. 43, No. 6, 1065–1072

0096-1523/17/$12.00 http://dx.doi.org/10.1037/xhp0000379

OBSERVATION

Out of Your Sight, Out of My Mind: Knowledge About Another Person's Visual Access Modulates Spontaneous Visuospatial Perspective-Taking

Martin Freundlieb, Natalie Sebanz, and Ágnes M. Kovács
Central European University

Accumulating evidence suggests that humans spontaneously adopt each other's visuospatial perspective (VSP), but many aspects about the underlying mechanisms remain unknown. The aim of this study was to investigate whether knowledge about another's visual access systematically modulates spontaneous VSP-taking. In a spatial compatibility task, a participant and a confederate sat at a 90°angle to each other, with visual stimuli being aligned vertically for the participants and horizontally for the confederate. In this task, VSP-taking is reflected in a spatial compatibility effect in the participant, because stimulus–response compatibility occurs only if the participant takes the confederate's perspective. We manipulated the visual access of the confederate during the task by means of glasses with adjustable shutters that allowed or prevented the confederate from seeing the visual stimuli. The results of 2 experiments showed that people only adopted their task partner's VSP if that person had unhindered visual access to the stimuli. Provided that the confederate had visual access to the participant's stimuli, VSP-taking occurred regardless of whether the confederate performed the same visual task as the participant (Experiment 1) or a different, auditory task (Experiment 2). The results suggest that knowledge about another's visual access is pivotal for triggering spontaneous VSP-taking, whereas having the same task is not. We discuss the possibility that spontaneous VSP-taking can effectively facilitate spatial alignment processes in social interaction.

Public Significance Statement
People virtually always have differing viewpoints on their surrounding environment. This study shows that we spontaneously take into account how somebody else perceives the environment, even in situations where we are not asked to do so, and we are likely not aware of doing so. This suggests that humans are endowed with a basic sensitivity to their conspecifics' viewpoints.

Keywords: visuospatial perspective-taking, mentalizing, spatial compatibility

Being able to relate to multiple individuals' viewpoints is a key component of social interactions. Our own visual perspective is virtually never perfectly aligned with the perspectives of the people with whom we are interacting. Instead, we might sometimes even find our perspectives to be opposite of each other. For instance, imagine that you want to draw your friend's attention to the fact that there is an eyelash on her cheek. In telling her you need to take into consideration that her right is your left side, and vice versa (Kessler & Thomson, 2010). Moreover, we often have practically no time to ponder on the other's perspective but instead need to quickly react to successfully interact with each other. Take a basketball player who—just at the right moment—needs to pass the ball at a particular angle to her teammate's appropriate hand so that he can go for an easy layup. To successfully interact with others, we need to be able to *spontaneously* understand and integrate information about differing perspectives.

Recent studies suggest that humans have a remarkable ability to take the perspective of others. However, as our review of the literature shows, little is known about the mechanisms underlying spontaneous visuospatial perspective-taking (VSP-taking), which involves computing how an object is perceived from somebody else's perspective. In particular, does knowledge about another's ability to see the object on which we have a different perspective play a role? Or are there more low-level mechanisms at work that are independent of knowledge about another's visual access? Addressing these questions was the aim of the present study.

This article was published Online First March 6, 2017.

Martin Freundlieb, Natalie Sebanz, and Ágnes M. Kovács, Department of Cognitive Science, Central European University.

This work was supported by the European Research Council (ERC), partly under the European Union's Seventh Framework Programme (FP7/2007–2013)/ERC starting grant (284236-REPCOLLAB) and by the ERC consolidator grant (616072-JAXPERTISE).

Correspondence concerning this article should be addressed to Martin Freundlieb, Department of Cognitive Science, Central European University, Oktober 6 utca 7, 1051 Budapest, Hungary. E-mail: Freundlieb_Martin@phd.ceu.edu

In the following, we first summarize research showing that people spontaneously process whether another agent can see a target object or not (visual perspective-taking, also referred to as Level-1 perspective-taking in the literature, cf. Flavell, Everett, Croft, & Flavell, 1981). Afterward, we discuss whether humans also spontaneously compute the location of objects relative to another person, infer what these objects look like from his or her point of view, and investigate how that impacts action planning (VSP-taking, also referred to as Level-2 perspective-taking, cf. Flavell et al., 1981). Finally, we move on to discuss how knowledge about another person's visual access might modulate the spontaneous adoption of her visuospatial perspective.

Spontaneous Visual Perspective-Taking

Recent research has investigated how and under which circumstances we spontaneously adopt somebody else's perspective (Freundlieb, Kovács, & Sebanz, 2016; Furlanetto, Becchio, Samson, & Apperly, 2016; Mazzarella, Hamilton, Trojano, Mastromauro, & Conson, 2012; Samson, Apperly, Braithwaite, Andrews, & Bodley Scott, 2010; Surtees, Apperly, & Samson, 2016, 2013; Tversky & Hard, 2009). For example, Samson and colleagues (2010) have shown that participants automatically process the content of an avatar's perspective, regardless of whether or not it is important for their task. Specifically, when making judgments about the total number of objects being visible in a given scene, participants spontaneously computed the number of objects that the avatar could see. The results showed that participants were significantly faster on trials in which their own perspective was consistent with the avatar's perspective, compared with when it was inconsistent (Samson et al., 2010).

It has been argued that in such a setup, participants might not actually process the visual perspective of the human-like avatar, as the same results were obtained when the avatar was exchanged with a mere direction-indicating symbol, like an arrow (cf. Santiesteban, Catmur, Hopkins, Bird, & Heyes, 2014). If an arrow produced the same results as the avatar, then—according to the alternative explanation—spontaneous visual perspective-taking effects are probably based on general attention-shifting mechanisms, rather than a process that is specifically sensitive to the agentive features and the perspective of somebody else (cf. Heyes, 2014). Some evidence against this alternative hypothesis has recently been put forward by Furlanetto and colleagues (2016), who replicated the original study by Samson et al. (2010) with a crucial modification. Specifically, the avatar wore either transparent or opaque goggles. We found it interesting that they only found evidence for automatic visual perspective-taking in the presence of an avatar wearing goggles when participants believed the goggles to be transparent, but not when they believed the goggles to be opaque (Furlanetto et al., 2016). This suggests that people are sensitive toward the visual access of somebody else when automatically computing the content of what another can see.

Spontaneous VSP-Taking and Action Planning

Recent studies indicate that in interactive settings, people spontaneously compute not only whether another can see an object, but also how an object or scene appears to a task partner (Elekes, Varga, & Kiraly, 2016; Surtees et al., 2016). This has been addressed in studies on VSP-taking in which the perception of the participant and a second person differs not in terms of the visibility of objects, but in terms of how they appear from two different perspectives. In a study by Surtees et al. (2016), participants were instructed to judge the magnitude of a single number, either sitting alone or opposite a partner. The results showed that participants' task performance was systematically modulated when sitting opposite their partners, such that responses were significantly faster on trials in which their perspectives were consistent with those of their task partners (e.g., on trials in which an "8" or a "5" would be shown), compared with trials in which their points of view were inconsistent with their task partners' (e.g., on trials in which a "6" or "9" would be shown).

Freundlieb et al. (2016) proposed that spontaneous VSP-taking affects not only perceptual judgments but also action planning processes. They found that when participants responded to stimuli arranged vertically from their perspectives with left and right responses, they showed a spatial compatibility effect when task partners were sitting at a 90° angle, so that the stimuli were arranged horizontally from the point of view of the task partner. More specifically, participants' reaction-time (RT) patterns showed that they were faster to respond on trials that were *compatible* compared with *incompatible* with regard to the task partner's perspective (Freundlieb et al., 2016). An interesting point is that this study also indicated that when acting together, adopting another's VSP can have facilitative effects on participants' performance.

Visual Access and Spontaneous VSP-Taking

Although evidence for spontaneous VSP-taking has been accumulating, many aspects concerning the underlying mechanisms remain unknown. In particular, it is still unclear to what extent spontaneous VSP-taking is modulated by knowledge about the visual access of another person and how that impacts one's own action planning. Of note, the study by Furlanetto and colleagues (2016) investigated visual perspective-taking and showed that humans indeed spontaneously encode whether or not an object can be seen by another person. In contrast, VSP-taking (that is, *how* an object is seen by another person) seems to emerge much later in development (Apperly & Butterfill, 2009; Flavell et al., 1981) and has yet to be shown in nonhuman animals (Call & Tomasello, 2008), indicating that VSP-taking might be cognitively more effortful than visual perspective-taking. Thus, the question remains whether VSP-taking effects can be explained with encoding how an object is perceived by another person, or by lower level processes not entailing such computations. One way to investigate this is to ask whether visual access modulates VSP-taking. Is it crucial for spontaneous VSP-taking that people attribute particular perceptual or knowledge states to the other person?

On the one hand, it could be argued that knowledge about the other's visual access plays a crucial role in triggering VSP-taking. We are sensitive to others' epistemic access from early on in life, as indicated by research in infants showing that their gaze-following (Meltzoff & Brooks, 2008) and eye-movement behaviors in a false belief task (Senju, Southgate, Snape, Leonard, & Csibra, 2011) depend on whether an observed actor is wearing an opaque or transparent blindfold. Rather than merely following directional cues, evidence suggests that adults engage in fairly elaborate computations of what others can see depending on their line of sight (Baker, Levin, & Saylor, 2016). Furthermore, joint attention modulates how people process images of hands (Böckler, Knoblich, & Sebanz, 2011) and faces (Böckler & Zwickel, 2013), leading to a switch from an egocentric to an altercentric reference frame, specifically, if a task partner is attending to the stimuli. Knowing that another individual can in principle observe the same object from a different VSP might thus constitute a necessary factor for triggering the spontaneous adoption of the other's VSP.

On the other hand, it has been proposed that VSP-taking could be based on an embodied cognitive process during which the self-perspective is physically aligned with the target perspective—regardless of whether the target perspective entails seeing the world from a social agent's viewpoint or, say, from a predefined point in space, such as an empty chair (see Kessler & Thomson, 2010). For instance, Kessler and Thomson (2010) investigated whether participants used different strategies if they had to adopt the perspective of a differently oriented chair, compared with adopting the perspective of a differently oriented human agent. Their results indicated that participants used the same kind of motoric embodiment (i.e., a computation of the sensory consequences of a mental rotation of the self-perspective) to change their VSP (Kessler & Thomson, 2010). This suggests that to understand where something is located relative to someone or something else, we need not necessarily attribute mental content, or, as Surtees et al. (2013) put it, ". . . for me to know that something is to your left is in no way dependent on you representing it as such" (p. 427, Surtees et al., 2013; cf. also Surtees, Noordzij, & Apperly, 2012).

This means that the attribution of a particular perceptual or knowledge state might not be a necessary prerequisite for spontaneous VSP-taking to occur. In particular, in the task used by Freundlieb et al. (2016), the mere presence of a task partner with a different spatial orientation might, by itself, have posed a sufficient cue to trigger the adoption of his perspective. Although the mere presence of a passive individual did not trigger VSP-taking in this study, it could still be the case that participants mentally rotated themselves into the other's position when he was actively performing a task, without attributing perceptual content to the other.

Current Study

To further specify the mechanism underlying spontaneous perspective-taking, we investigated whether the visual access of another person affects spontaneous VSP-taking. Specifically, we aimed to disentangle whether spontaneous VSP-taking is merely based on physical alignment processes (i.e., the rotation of the self into the target perspective) or whether specific forms of spontaneous VSP-taking depend on knowledge about the visual access of the other in a task in which the other's perspective was never mentioned, and thus, not highlighted in any way.

To this end, we used a task in which participants were seated at a 90° angle to a co-actor. They were instructed to perform an orthogonal stimulus–response-compatibility task (SRC, cf. Craft & Simon, 1970; Simon, 1990) on a horizontally mounted computer display (see Figure 1). Given the sitting position of the confederate and the participant, the stimuli could be seen from two different VSPs—they either appeared vertically (from the participant's perspective) or horizontally (from the confederate's perspective). As the participant saw the stimuli along a vertical dimension (up/down) and responded to them on a horizontal dimension (that is, with left/right button presses), there was no spatial overlap. From the confederate's point of view though, stimuli appeared horizontally (left/right) and could therefore coincide with the participant's responses (left/right). Thus, measuring responses according to the spatial position of the stimuli allowed us to test effects of VSP-taking on participants' performance (Freundlieb et al., 2016).

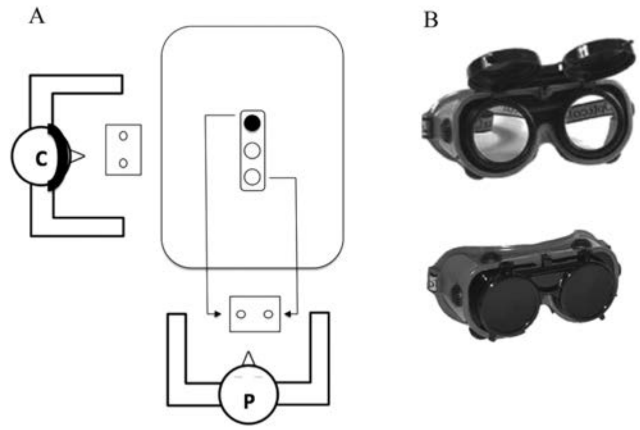

Figure 1. (A) Sketch of the experimental setup for Experiment 1. Participant "P" sat at a 90° angle to Confederate "C;" an example of the compatible block during the blindfolded condition. The arrows indicate the participant's mapping. (B) Photograph of the shutter glasses in the transparent and opaque states.

We modulated the visual access of the confederate by using goggles that would either allow or prevent the confederate from seeing the stimuli on the screen. If participants showed a spatial compatibility effect depending on whether or not the confederate had visual access to the stimuli, this would provide evidence that they are relying on the confederate's visual access during spontaneous VSP-taking.

Experiment 1

To investigate how knowledge about another's visual access modulates spontaneous VSP-taking, we compared two conditions in which the confederate's actions remained the same, but his visual access to the stimuli was manipulated. Whereas the participants performed a visual SRC task in both conditions, the confederate performed either a visual task (i.e., the *seeing* condition) or was blindfolded and performed an auditory task (i.e., the *blindfolded* condition). In both conditions, the confederate was instructed to give the same right- and left-button press responses.

If there was a spatial compatibility effect only in the condition in which the confederate could *see* the stimuli, then this would support the claim that the other's visual access is a necessary factor for triggering spontaneous VSP-taking. In contrast, if participants' responses were unaffected by the confederate having (or *not* having) visual access to the stimuli, then this would suggest that the other's body orientation and the fact that he performed responses along a right–left dimension triggered a mental rotation into his position—independent of his visual access.

Method

Participants. Eighteen participants (mean age = 20.8 years; 13 women; three left-handed) signed up for this study and received gift vouchers for their participation. Two participants did not meet the inclusion criterion of having more than 90% successful trials within each experimental condition, leaving 16 participants (mean age = 20.7 years; 11 women; three left-handed) for the analysis. All participants were naïve to the purpose of the study, reported normal or corrected to normal vision, and signed informed consent prior to the experiment.

Stimuli and apparatus. The stimuli consisted of a rectangle (subtending 5.73° of visual angle vertically and 3.27° horizontally) containing three empty circles (each subtending 1.64° of visual angle) at equal distance to each other. During the trials, one out of these three circles (either the one at the top, or the one at the bottom, but never the circle in the middle) then appeared as a black disk in place of the empty circle (see Figure 1A). These two types of stimuli were shown on a horizontally arranged 27-in. iMac (Mid-2011). The monitor was mounted at a height of about 25 cm from the floor. Responses were given on two button boxes (ioLab Response Box, Github, Inc., San Francisco, CA), which both the participant and the confederate placed on their laps. The button boxes were partly covered with a piece of carton so that only the two buttons used to respond (i.e., the buttons farthest to the left and right) were visible. Throughout the experiment, the confederate wore a pair of lift-front goggles (Lux Optical, Worldwide Euro Protection, Luxembourg, see Figure 1B). These goggles had small shutters that could either be lifted up, in which case one had unhindered vision through transparent Plexiglas, or flapped down, in which case black tape on the shutters blocked vision.

Design and procedure. For the participant as well as for the confederate, who was oriented in a 90° angle to the participant, viewing distance was approximately 70 cm. Throughout the entire study, the same young man acted as the confederate. Each trial started with the presentation of a fixation cross (subtending 0.66° of visual angle, presented in the center of the screen) for 350 ms. Subsequently, the screen turned blank for 100 ms after which, randomly, one of the two stimuli (top black disk vs. bottom black disk) was shown for 1200 ms. Participants performed two conditions (blindfolded and seeing) with two blocks (compatible and incompatible) each. Each block contained 100 trials and participants were asked to respond as fast and accurately as possible. To establish different compatibility relations, we varied the sitting position of the confederate and the stimulus–response mapping of the participants.

In one half of the experiment, participants were instructed to respond to the appearance of the top black disk by pressing the right button on the button box with their right index finger and to respond to the bottom black disk by pressing the left button with their left index finger, respectively. In the other half, the mapping was reversed and they were thus instructed to respond to the appearance of the top black disk with a left and to the appearance of the bottom black disk with a right button press. In the compatible condition, the mapping of the participant concurred with the spatial orientation of the confederate, but in the incompatible condition, it did not. For instance, if the confederate sat 90° to the left of the participant, participants were instructed with the "up-left, down-right" mapping in the compatible, and with the "up-right, down-left" mapping in the incompatible block (see Figure 1A).

The task of the confederate changed throughout the experiment, which was crucial. During the seeing condition, the confederate was asked to flap the shutters of his goggles up and respond to the visual stimuli on the screen. Specifically, the confederate was instructed to respond with a left button press if a black disk appeared—from his point of view—on the left side of the screen, and with a right button press if a black disk appeared on the right side of the screen. In the other half of the trials (i.e., during the blindfolded condition), the confederate was given a pair of headphones and was asked to flap the shutters of his goggles down to respond to auditory stimuli. He was instructed to respond to a high tone with a "right" and to a low tone with a "left" button press on the button box. The high and low tones appeared at the same time as the visual stimuli, but could only be heard through the headphones. To ensure that the confederate performed the same actions in the two conditions, the high tone always appeared together with the up stimulus, whereas the low tone appeared together with the down stimulus.

Before the blindfolded condition started, a short practice block was conducted, during which the participant and the confederate switched tasks. This practice block was conducted to familiarize participants with the task involving the goggles. Hence, for the duration of the practice block, the experimenter asked the participants to sit where the confederate would sit later on (and vice versa). The instructions that were given (both for the auditory and for the visual task) during this practice block were identical to the instructions given during the experimental condition. After 10 practice trials, the practice block was over and both the participant and the confederate were instructed to swap places, so that for the experimental trials, the participant always performed the visual SRC task while the confederate consecutively performed the auditory task in addition to the visual SRC task. It is important to note, participants could not hear the tones to which the confederate responded when he was performing the auditory task. Before each block, 10 practice trials familiarized the participants with the task. These were later excluded from the statistical analysis.

The order of conditions (blindfolded vs. seeing), the position of the confederate (90° to the left vs. to the right of the participant), as well as the order of mappings (compatible vs. incompatible) was counterbalanced across participants.

Data analysis. Errors (i.e., trials in which the wrong button or no button at all was pressed) and RTs more than 2 *SD*s away from each participant's condition means were excluded from the RT analysis. Both the two condition means for correct-response RTs and errors for each participant were subjected to separate two-way, repeated-measures analyses of variance (ANOVAs) with the factors Vision Other (blindfolded vs. seeing) and Compatibility (compatible vs. incompatible).

Results

For the RT analysis, 2.03% of the trials were removed as errors and 3.77% of the trials were removed for being more than 2 *SD*s away from each participant's condition means, leaving 94.2% of the raw data as correct-response trials. The error analysis revealed a tendency toward a significant main effect of Compatibility, $F(1, 15) = 15$, $p = .06$, $\eta_p^2 = .23$) showing that participants made more errors during compatible ($M = 2.25\%$ errors) than incompatible ($M = 1.06\%$ errors) trials.[1] Neither the main effect of Vision Other, $F(1, 15) < 1$, $p = .99$, $\eta_p^2 < .01$., nor the interaction between Vision Other and Compatibility, $F(1, 15) = 3.08$, $p = .10$, $\eta_p^2 = .17$, was significant.

The RT analysis revealed a significant interaction between Vision Other and Compatibility, $F(1, 15) = 5.35$, $p = .03$, $\eta_p^2 = .26$. In post hoc analyses, pairwise comparisons showed a significant difference in RTs between the compatible ($M = 349$, $SD = 26$) and incompatible ($M = 363$, $SD = 29$) blocks only in the seeing condition, $t(15) = -2.63$, $p = .02$, two-tailed, but not in the blindfolded condition ($M = 359$, $SD = 38$ and $M = 362$, $SD = 42$, for compatible and incompatible trials, respectively), $t(15) = -.53$, $p = .60$, two-tailed (see Figure 2). None of the other pairwise comparisons were significant (all ps $> .15$). There was neither a significant main effect of Vision Other $F(1, 15) < 1$, $p = .53$, $\eta_p^2 = .03$, nor of Compatibility, $F(1, 15) = 2.9$, $p = .11$, $\eta_p^2 = .16$.

Discussion

Experiment 1 showed a spatial Compatibility effect selectively when the confederate was able to see and responded to the visual stimuli. This suggests that participants spontaneously adopted the other's VSP depending on the other's visual access. Because the confederate's ability to see the stimuli was necessary to evoke the Compatibility effect, one could therefore contend that participants indeed computed how the stimuli were *seen* by the confederate. Because the confederate's position/posture did not change between conditions, it can be ruled out that it was merely the directionality of his front features (that is, the direction of body, forehead, nose, etc.) that had triggered spontaneous VSP-taking.

However, in Experiment 1 the confederate performed a visual task in the seeing condition and an auditory task in the blindfolded condition, whereas the participant performed a visual task in both conditions. It could be argued that the data of Experiment 1 can be explained in virtue of the (changing) tasks that both the participant and the confederate needed to perform. In particular, it might be possible that spontaneous VSP-taking only occurs if both people are performing the same task. If this were the case, then the absence of the effect during the blindfolded condition in Experiment 1 could be merely due to the participant and the confederate performing two different tasks—the former a visual, the latter an auditory task.

Second, one could argue that if participants monitored the confederate's task performance, it led to differences in terms of general task complexity between the two conditions. In the seeing condition, participants were performing the very same visual SRC task as the confederate; in the blindfolded condition, monitoring the other's task implied inferring the auditory stimulus based on the confederate's key presses. To better understand the role of task similarity and to rule out potential confounds, we conducted Experiment 2.

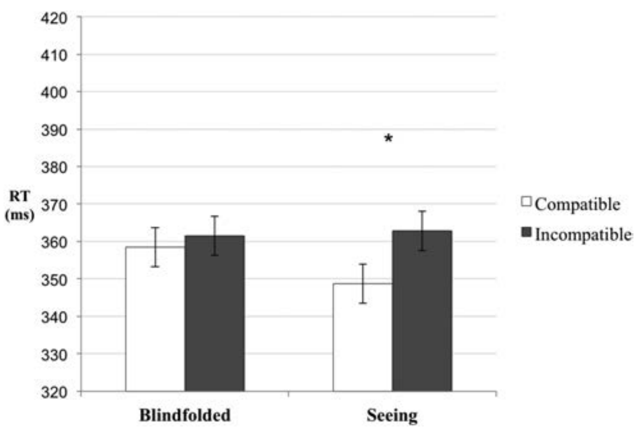

Figure 2. Mean RTs in the blindfolded and seeing conditions in Experiment 1. Error bars display within-subject confidence intervals according to Loftus and Masson (1994). * $p < .05$.

Experiment 2

Experiment 2 investigated the alternative explanation that spontaneous VSP-taking hinged on differences between the tasks that the participant and the confederate needed to perform in both the seeing and blindfolded conditions of Experiment 1, rather than on knowledge about the other's visual access. To rule out potential confounds, the confederate performed the same auditory task throughout the two conditions. The predictions of Experiment 2 were as follows: If spontaneous VSP-taking depends on performing the same task as the other person, then the differences between conditions should disappear when the participant and the confederate perform two different tasks in both conditions. It is important to note, this should be independent of whether or not the confederate has visual access to the stimuli. In contrast, if spontaneous VSP-taking depends on whether or not the other has unblocked visual access to the stimuli, then the Compatibility effect should only occur when the confederate has visual access to the stimuli, regardless of the fact that the confederate's task is different from the participant's.

Method

Participants. Eighteen new participants (mean age = 21.83 years; nine women; one left-handed) signed up for this study and received gift vouchers for their participation. Two participants did not meet the inclusion criterion of having more than 90% successful trials within each experimental condition, leaving 16 participants (mean age = 21.75 years; seven women; one left-handed) for the analysis. All participants were naïve to the purpose of the study, reported normal or corrected-to-normal vision, and signed informed consent prior to the experiment.

Stimuli and apparatus. The stimuli and the apparatus were identical to Experiment 1.

[1] The fact that there was a tendency toward a significant main effect for Compatibility in the error analysis could indicate that there was a speed–accuracy trade-off. However, as participants were not generally faster in compatible versus incompatible trials (there was a difference between compatible and incompatible trials only in the seeing condition), such a speed–accuracy trade-off is not supported by the data.

Procedure. Participants performed two conditions (blindfolded and seeing) with two blocks (compatible and incompatible), respectively. Each block contained 100 trials. The participants' task was identical to Experiment 1 and they were asked to respond as fast and accurately as possible. In contrast to Experiment 1, the confederate now performed an auditory task throughout the entire experiment. The occurrence of the type of tone (high vs. low) was independent of the location of the visual stimulus in Experiment 2. That is, the appearance of a stimulus at the upper side of the screen could now co-occur with a high or a low tone (with the same holding true for the stimuli at the lower end of the screen). The tones were played through headphones so that they were only audible for the confederate but not for the participant. Other than that, the procedure was identical to Experiment 1. In half of the trials, the confederate's shutters were flapped down (blindfolded), and in the other half, the shutters were flapped up (seeing) and the confederate had unblocked visual access to the stimuli on the screen. Before each condition, 10 practice trials familiarized the participants with the task. These were later excluded from the statistical analysis.

The order of conditions (blindfolded vs. seeing), the position of the confederate (90° to the left vs. to the right of the participant), as well as the order of mappings (compatible vs. incompatible) was counterbalanced across participants.

Data analysis. Errors (i.e., trials in which the wrong button or no button at all was pressed) and RTs more than 2 *SD*s from each participant's condition means were excluded from the RT analysis. Both the two condition means for correct response RTs and errors for each participant were subjected to separate two-way, repeated-measures ANOVAs with the factors Vision Other (blindfolded vs. seeing) and Compatibility (compatible vs. incompatible).

Results

For the RT analysis, 1.11% of the trials were removed as errors and 4.03% were removed for being more than 2 *SD*s away from each participant's condition means, leaving 94.86% of the raw data as correct-response trials. The error analysis did not show any effect of Compatibility, $F(1, 15) < 1$, $p = .99$, $\eta_p^2 < .01$), Vision Other, $F(1, 15) < 1$, $p = .79$, $\eta_p^2 < .01$., or the interaction between the two, $F(1, 15) < 1$, $p = .82$, $\eta_p^2 < .01$.

The RT analysis revealed a significant interaction between Vision Other and Compatibility, $F(1, 15) = 18.93$, $p < .01$, $\eta_p^2 = .56$. In post hoc analyses, pairwise comparisons showed a significant difference in RTs between the compatible ($M = 366$, $SD = 27$) and incompatible ($M = 401$, $SD = 42$) blocks only in the seeing condition, $t(15) = -3.69$, $p = .002$, two-tailed, but not in the blindfolded condition ($M = 397$, $SD = 61$ and $M = 382$, $SD = 25$ for compatible and incompatible trials, respectively), $t(15) = 1.3$, $p = .20$ (see Figure 3). Furthermore, there was a significant difference in RTs between the seeing-compatible ($M = 366$, $SD = 27$) and blindfolded-incompatible ($M = 382$, $SD = 25$) trials, $t(15) = 2.58$, $p = .02$, two-tailed, and a tendency toward a difference between seeing-compatible ($M = 366$, $SD = 27$) and blindfolded-compatible ($M = 397$, $SD = 61$) trials, $t(15) = 2.05$, $p = .058$, two-tailed. The two remaining pairwise comparisons were not significant (both *p*s $> .15$). Finally, there was neither a significant main effect of Vision Other, $F(1, 15) < 1$, $p = .61$, $\eta_p^2 = .02$, nor of Compatibility, $F(1, 15) = 1.3$, $p = .27$, $\eta_p^2 = .08$.

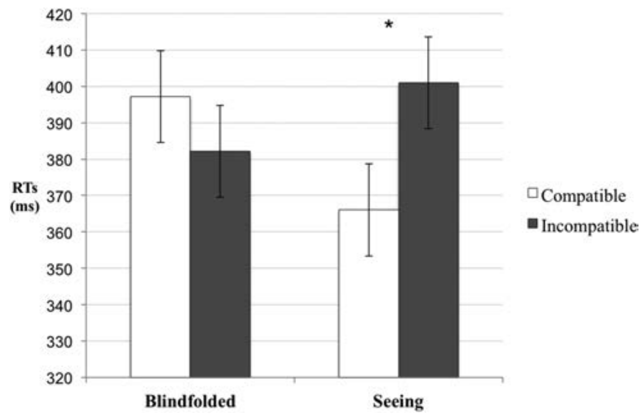

Figure 3. Mean RTs in the blindfolded and seeing conditions in Experiment 2. Error bars display within-subject confidence intervals according to Loftus and Masson (1994). * $p < .05$.

Discussion

The results suggest that participants adopted the confederate's VSP if he had unblocked visual access to the stimuli. This confirms the results obtained in Experiment 1, indicating that VSP-taking depends on others' visual access. Participants showed a spatial Compatibility effect when the confederate could see the visual stimuli they responded to, even though the confederate performed an auditory task that was independent of the participants' visual task. These results are in line with findings by Surtees and colleagues (2016), showing that spontaneous VSP-taking is not restricted to situations where people perform the same tasks. Although Surtees et al. found evidence for spontaneous VSP-taking when two participants responded to two different aspects of the same visual stimuli (e.g., one participant responded to number magnitude and the other responded to a surface feature, cf. Surtees et al., 2016), our results demonstrate that spontaneous VSP-taking can occur even when the tasks are performed in different sensory modalities.

Finally, the data of Experiment 2 suggests that compared with all other conditions, participants were particularly fast to respond during the compatible trials in the seeing condition. This is in line with earlier findings (Freundlieb et al., 2016) supporting the claim that, under certain circumstances, spontaneous VSP-taking might have facilitory effects.

General Discussion

The aim of this study was to investigate the mechanisms underlying spontaneous VSP-taking. Specifically, we examined whether knowledge about another person's visual access systematically modulates perspective-taking. To this end we used a task that has previously been shown to elicit spontaneous VSP-taking (Freundlieb et al., 2016). We manipulated the visual access of the other person (a confederate) during the task by means of glasses with adjustable shutters that allowed or prevented the confederate from seeing the visual stimuli. The results show that participants only adopted the other's VSP if he had unhindered visual access to the stimuli but regardless of whether or not he performed the same visual task or a different auditory task. Our study therefore suggests that spontaneous VSP-taking is indeed modulated by knowledge about another person's visual access.

Our findings contribute to current debates about the mechanisms underlying perspective-taking. It has been suggested that in addition to a comparatively slow but elaborate mentalizing system, humans possess another 'simple perspective-taking system' (cf. Samson et al., 2010), which enables them to quickly and efficiently process what another agent can see (cf. Qureshi, Apperly, & Samson, 2010; Ramsey, Hansen, Apperly, & Samson, 2013), especially in contexts where the other is performing actions (cf. Frischen, Loach, & Tipper, 2009; Surtees et al., 2016; Tversky & Hard, 2009; Zwickel, 2009). In contrast, it has also been proposed that much of the evidence that has been connected to the concept of perspective-taking can be captured more parsimoniously through domain-general processes such as attention reorienting or spatial referencing (Heyes, 2014; Santiesteban et al., 2014; Santiesteban, Shah, White, Bird, & Heyes, 2015). On this account, if we observe somebody else confronted with a different amount of target objects than ourselves (like in the study conducted by Samson et al., 2010) we might not actually have to process *that* he or she can actually see and consequently represents the seen objects. Instead, it could be that domain-general cognitive mechanisms pick up on salient features (such as the other's body orientation), resulting in attentional reorienting and producing the same kind of responses that are typically ascribed to perspective-taking or implicit mentalizing (Heyes, 2014).

Some evidence against these low-level explanations has been provided by Furlanetto and colleagues (2016), who showed that information about the visual access of the other person is, in fact, pivotal for engaging in automatic visual perspective-taking and hence, that the mere exhibition of front features (i.e., the direction of the body, forehead, nose, etc.) is not sufficient to trigger visual perspective-taking (Furlanetto et al., 2016). The findings of the present study further extend this claim to the domain of VSP-taking. Using a visuospatial paradigm in which the other's perspective was not prompted in any way (participants never had to consider the other's perspective, in contrast to Furlanetto et al., 2016), we showed that, beyond automatically processing the content of what another agent can see, humans are also able to spontaneously process *how* something is seen from another person's point of view. Furthermore, although other studies have reported effects of perspective-taking in tasks that required participants to make judgments about the location of objects (Tversky & Hard, 2009; Kessler & Thomson, 2010) or had to indicate what could be seen from a particular perspective (Furlanetto et al., 2016; Samson et al., 2010), our results suggest that participants adopted another's VSP by all means spontaneously, that is, without being prompted to do so. It is important to note, spontaneous VSP-taking seems to hinge not only on the other person being actively engaged in a task (cf. Freundlieb et al., 2016; Frischen et al., 2009; Surtees et al., 2016), but also on the other person having visual access to the stimuli. Only if participants knew that the other had unhindered visual access to the stimuli did they spontaneously adopt his perspective and processed the stimuli as if they were seen from the other person's perspective. Thus, we believe this is the first study to show how visual access triggers the spontaneous integration of somebody else's VSP into one's own action planning.

We believe that the mechanism underlying the observed effects entails participants shifting from processing the scene according to their own points of view (or egocentrically) to processing the scene from the others' points of view (or altercentrically, cf. Ramsey et al., 2013; Samson et al., 2010). Previous studies have already shown that task performance can be affected in the presence of another person whose viewpoint differs from our own (Böckler et al., 2011; Conson, Mazzarella, Donnarumma, & Trojano, 2012; Furlanetto et al., 2016; Ramsey et al., 2013; Samson et al., 2010), especially when the other person is perceived as potentially interacting with the object in the common focus of attention (Freundlieb et al., 2016; Frischen et al., 2009; Furlanetto, Cavallo, Manera, Tversky, & Becchio, 2013; Mazzarella et al., 2012; Surtees et al., 2016; Tversky & Hard, 2009). The switching of reference frames in our study might have been prompted by the fact that the other person was performing a task while having visual access to the stimuli. Processing the stimuli in an altercentric way then led to a spatial overlap between the left–right dimension of the stimuli and the left–right dimension of participants' responses. Finally, this overlap is reflected in the spatial Compatibility effect that we observed in both experiments.

Functionally, such a mechanism could be helpful during interpersonal coordination, as it could facilitate the integration of diverging spatial perspectives into one common format. Specifically, the spontaneous integration of somebody else's VSP into one's own action planning might serve the function of aligning actions that are performed in close vicinity—but from different VSPs (cf. Creem-Regehr, Gagnon, Geuss, & Stefanucci, 2013). The fact that we found evidence for such an integration, even when both actors performed different tasks, suggests that this mechanism is quite general, that is, it does not depend on performing the same task together—as long as the other person has visual access to the same stimuli and is an intentionally acting agent (see Freundlieb et al., 2016; Surtees et al., 2016). A closer look at Experiment 2 of this study revealed that adopting the other's VSP actually sped up participants' performance during the task, which we found interesting. Numerically, this pattern also seems to have been present in Experiment 1; however, the statistical comparison failed to reach significance. Thus, further experiments are required to make a more compelling argument for the hypothesis that, given the right circumstances, spontaneous VSP-taking can effectively facilitate spatial alignment processes, which are required in many social interactions (cf. Freundlieb et al., 2016).

In conclusion, we found that knowledge about another person's visual access systematically modulated the spontaneous integration of another person's VSP into one's own action planning. Our findings show that participants only adopted the other person's VSP if he had unhindered visual access to the stimuli, but regardless of whether or not he performed the same task or a different task. Furthermore, our data suggest that, when people perform a task together, adopting the other's VSP might be facilitating and possibly lead to improved task performance. In turn, this might assist with interpersonal coordination in situations where we need to quickly integrate the diverging perspectives of multiple agents.

References

Apperly, I. A., & Butterfill, S. A. (2009). Do humans have two systems to track beliefs and belief-like states? *Psychological Review, 116,* 953–970. http://dx.doi.org/10.1037/a0016923

Baker, L. J., Levin, D. T., & Saylor, M. M. (2016). The extent of default visual perspective taking in complex layouts. *Journal of Experimental*

Psychology: Human Perception and Performance, 42, 508–516. http://dx.doi.org/10.1037/xhp0000164

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,* 531–545. http://dx.doi.org/10.1007/s00221-011-2625-z

Böckler, A., & Zwickel, J. (2013). Influences of spontaneous perspective taking on spatial and identity processing of faces. *Social Cognitive and Affective Neuroscience, 8,* 735–740. http://dx.doi.org/10.1093/scan/nss061

Call, J., & Tomasello, M. (2008). Does the chimpanzee have a theory of mind? 30 years later. *Trends in Cognitive Sciences, 12,* 187–192. http://dx.doi.org/10.1016/j.tics.2008.02.010

Conson, M., Mazzarella, E., Donnarumma, C., & Trojano, L. (2012). Judging hand laterality from my or your point of view: Interactions between motor imagery and visual perspective. *Neuroscience Letters, 530,* 35–40. http://dx.doi.org/10.1016/j.neulet.2012.09.051

Craft, J. L., & Simon, J. R. (1970). Processing symbolic information from a visual display: Interference from an irrelevant directional cue. *Journal of Experimental Psychology, 83,* 415–420. http://dx.doi.org/10.1037/h0028843

Creem-Regehr, S. H., Gagnon, K. T., Geuss, M. N., & Stefanucci, J. K. (2013). Relating spatial perspective taking to the perception of other's affordances: Providing a foundation for predicting the future behavior of others. *Frontiers in Human Neuroscience, 7,* 596. http://dx.doi.org/10.3389/fnhum.2013.00596

Elekes, F., Varga, M., & Király, I. (2016). Evidence for spontaneous Level-2 perspective taking in adults. *Consciousness and Cognition, 41,* 93–103. http://dx.doi.org/10.1016/j.concog.2016.02.010

Flavell, J. H., Everett, B. A., Croft, K., & Flavell, E. R. (1981). Young childrens knowledge about visual-perception: Further evidence for the Level-1–Level-2 distinction. *Developmental Psychology, 17,* 99–103. http://dx.doi.org/10.1037/0012-1649.17.1.99

Freundlieb, M., Kovács, Á. M., & Sebanz, N. (2016). When do humans spontaneously adopt another's visuospatial perspective? *Journal of Experimental Psychology: Human Perception and Performance, 42,* 401–412. http://dx.doi.org/10.1037/xhp0000153

Frischen, A., Loach, D., & Tipper, S. P. (2009). Seeing the world through another person's eyes: Simulating selective attention via action observation. *Cognition, 111,* 212–218. http://dx.doi.org/10.1016/j.cognition.2009.02.003

Furlanetto, T., Becchio, C., Samson, D., & Apperly, I. (2016). Altercentric interference in Level 1 visual perspective taking reflects the ascription of mental states, not submentalizing. *Journal of Experimental Psychology: Human Perception and Performance, 42,* 158–163.

Furlanetto, T., Cavallo, A., Manera, V., Tversky, B., & Becchio, C. (2013). Through your eyes: Incongruence of gaze and action increases spontaneous perspective taking. *Frontiers in Human Neuroscience, 7,* 455. http://dx.doi.org/10.3389/fnhum.2013.00455

Heyes, C. (2014). Submentalizing: I am not really reading your mind. *Perspectives on Psychological Science, 9,* 131–143. http://dx.doi.org/10.1177/1745691613518076

Kessler, K., & Thomson, L. A. (2010). The embodied nature of spatial perspective taking: Embodied transformation versus sensorimotor interference. *Cognition, 114,* 72–88. http://dx.doi.org/10.1016/j.cognition.2009.08.015

Loftus, G. R., & Masson, M. E. (1994). Using confidence intervals in within-subject designs. *Psychonomic Bulletin & Review, 1,* 476–490. http://dx.doi.org/10.3758/BF03210951

Mazzarella, E., Hamilton, A., Trojano, L., Mastromauro, B., & Conson, M. (2012). Observation of another's action but not eye gaze triggers allocentric visual perspective. *The Quarterly Journal of Experimental Psychology, 65,* 2447–2460. http://dx.doi.org/10.1080/17470218.2012.697905

Meltzoff, A. N., & Brooks, R. (2008). Self-experience as a mechanism for learning about others: A training study in social cognition. *Developmental Psychology, 44,* 1257–1265. http://dx.doi.org/10.1037/a0012888

Qureshi, A. W., Apperly, I. A., & Samson, D. (2010). Executive function is necessary for perspective selection, not Level-1 visual perspective calculation: Evidence from a dual-task study of adults. *Cognition, 117,* 230–236. http://dx.doi.org/10.1016/j.cognition.2010.08.003

Ramsey, R., Hansen, P., Apperly, I., & Samson, D. (2013). Seeing it my way or your way: Frontoparietal brain areas sustain viewpoint-independent perspective selection processes. *Journal of Cognitive Neuroscience, 25,* 670–684. http://dx.doi.org/10.1162/jocn_a_00345

Samson, D., Apperly, I. A., Braithwaite, J. J., Andrews, B. J., & Bodley Scott, S. E. (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,* 1255–1266. http://dx.doi.org/10.1037/a0018729

Santiesteban, I., Catmur, C., Hopkins, S. C., Bird, G., & Heyes, C. (2014). Avatars and arrows: Implicit mentalizing or domain-general processing? *Journal of Experimental Psychology: Human Perception and Performance, 40,* 929–937. http://dx.doi.org/10.1037/a0035175

Santiesteban, I., Shah, P., White, S., Bird, G., & Heyes, C. (2015). Mentalizing or submentalizing in a communication task? Evidence from autism and a camera control. *Psychonomic Bulletin & Review, 22,* 844–849. http://dx.doi.org/10.3758/s13423-014-0716-0

Senju, A., Southgate, V., Snape, C., Leonard, M., & Csibra, G. (2011). Do 18-month-olds really attribute mental states to others? A critical test. *Psychological science, 22,* 878–880. http://dx.doi.org/10.1177/0956797611411584

Simon, J. R. (1990). The effects of an irrelevant directional cue on human information processing. In R. W. Proctor & T. G. Reeve (Eds.), *Stimulus–response compatibility: An integrated perspective* (pp. 31–86). Amsterdam, the Netherlands: North-Holland. http://dx.doi.org/10.1016/S0166-4115(08)61218-2

Surtees, A., Apperly, I., & Samson, D. (2013). Similarities and differences in visual and spatial perspective-taking processes. *Cognition, 129,* 426–438. http://dx.doi.org/10.1016/j.cognition.2013.06.008

Surtees, A., Apperly, I., & Samson, D. (2016). I've got your number: Spontaneous perspective-taking in an interactive task. *Cognition, 150,* 43–52. http://dx.doi.org/10.1016/j.cognition.2016.01.014

Surtees, A. D., Noordzij, M. L., & Apperly, I. A. (2012). Sometimes losing your self in space: Children's and adults' spontaneous use of multiple spatial reference frames. *Developmental Psychology, 48,* 185–191. http://dx.doi.org/10.1037/a0025863

Tversky, B., & Hard, B. M. (2009). Embodied and disembodied cognition: Spatial perspective-taking. *Cognition, 110,* 124–129. http://dx.doi.org/10.1016/j.cognition.2008.10.008

Zwickel, J. (2009). Agency attribution and visuospatial perspective taking. *Psychonomic Bulletin & Review, 16,* 1089–1093. http://dx.doi.org/10.3758/PBR.16.6.1089

Received July 15, 2016
Revision received December 12, 2016
Accepted December 19, 2016 ■