

When Do Humans Spontaneously Adopt Another's Visuospatial Perspective?

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Perspective-taking is a key component of social interactions. However, there is an ongoing controversy about whether, when and how instances of spontaneous visuospatial perspective-taking occur. The aim of this study was to investigate the underlying factors as well as boundary conditions that characterize the spontaneous adoption of another person's visuospatial perspective (VSP) during social interactions. We used a novel paradigm, in which a participant and a confederate performed a simple stimulus-response (SR) compatibility task sitting at a 90° angle to each other. In this set-up, participants would show a spatial compatibility effect only if they adopted the confederate's VSP. In a series of 5 experiments we found that participants reliably adopted the VSP of the confederate, as long as he was perceived as an intentionally acting agent. Our results therefore show that humans are able to spontaneously adopt the differing VSP of another agent and that there is a tight link between perspective-taking and performing actions together. The results suggest that spontaneous VSP-taking can effectively facilitate and speed up spatial alignment processes accruing from dynamic interactions in multiagent environments.

Keywords: perspective-taking, spatial compatibility, joint task representation

Whether we steer a remote control helicopter, navigate fictional characters through a complex maze in a video game, or simply guide terribly lost friends to their destination over the phone, our daily life constantly challenges us with a plethora of visual perspectives that are often different to (if not competing with) our own point of view. Moreover, in many situations we do not have the possibility to ponder over the divergence of our own and somebody else's vantage point but instead need to make quick decisions in order to successfully interact with others. Take, for instance, a soccer player who wants to pass a ball over to a moving teammate while dribbling past a swarm of opponents during a match.

Recent research suggests that we are equipped with sophisticated mechanisms that allow us to track and flexibly integrate varying perspectives on multiple levels. This is reflected, for example, in our fundamental comprehension that one and the same thing can be viewed or construed differently depending on the chosen standpoint—whether this requires an epistemic, conceptual, affective, or visuospatial perspective (see Perner, Brandl, & Garnham, 2003). Functionally, the ability to flexibly adopt another person's perspective for example, while jointly attending to an object, is pivotal in order to enable the formation of joint goals, as well as the successive coordination of actions (Bratman, 1992).

While managing different perspectives can be challenging due to egocentric biases (see Keysar, Barr, Balin, & Brauner, 2000; Keysar, Lin, & Barr, 2003; Dumontheil, Apperly, & Blakemore, 2010; Mattan, Quinn, Apperly, Sui, & Rothstein, 2015), accumulating evidence indicates that people are remarkably sensitive toward other agents' perspectives (Michelon & Zacks, 2006; Qureshi, Apperly, & Samson, 2010; Ramsey, Hansen, Apperly, & Samson, 2013; Samson, Apperly, Braithwaite, Andrews, & Bodley Scott, 2010; Tversky & Hard, 2009; Vogeley & Fink, 2003; Zwicker, 2009). When being asked to make judgments about what they themselves could see, participants reliably showed *altercentric intrusion*, that is they automatically took into account what somebody else could or could not see—even if this was completely irrelevant for their task (see Samson et al., 2010). For instance, when participants saw three disks while an avatar could only see one disk, their response times were slower compared with a condition where both saw the same amount of disks (Samson et al., 2010).

Although people's sensitivity to others' perspectives is in itself noteworthy, an important point of debate in the literature is what exactly adopting another's perspective entails, and how it affects one's own action planning. The finding by Samson, Apperly, Braithwaite, Andrews, and Bodley Scott (2010) shows that we readily compute *whether* somebody else can see a target object or not. However, one could argue that perspective-taking entails more than that. For example, we sometimes need to compute the location of objects relative to others, and to infer what these objects look like from their perspective. In other words, we need to be able to take into account the differing *visuospatial perspective* (VSP) of another person.

It has been argued that judging whether another agent can or cannot see an object, and judging the location of the object with respect to that agent (that is, taking the VSP of that agent) involves two different perspective-taking processes (Michelon & Zacks,

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

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2006). Whereas so-called *line-of-sight* or *visibility* judgments appear to be very rapid and effortless, judging the relative location from a particular perspective requires a transformation of one's egocentric reference frame and is therefore assumed to be more effortful, leading to more errors and increased response latencies (cf. Kessler & Thomson, 2010; Surtees, Apperly, & Samson, 2013). However, given that VSP-taking is argued to play an important role in social interactions (Bratman, 1992; Creem-Regehr, Gagnon, Geuss, & Stefanucci, 2013), it should not always manifest through interference and hence, be detrimental on performance. There should be situations in which one can also find evidence for the opposite, that is where VSP-taking actually has a positive effect on performance. For instance, when we need to guide someone to a specific location on the phone, we should be able to flexibly adopt and use his viewpoint in order to achieve our communicative goals.

Visuospatial Perspective-Taking in Communicative Tasks and Memory Research

Several studies have investigated how we retrieve spatial information in the presence of another person (Galati, Michael, Mello, Greenauer, & Avraamides, 2013; Schober, 1995; Shelton & McNamara, 2004; Sjolund, Erdman, & Kelly, 2014). In most of these studies, pairs of participants worked together, with one participant (the "director") being instructed to describe a layout of objects to the other participant (the "matcher"), who then attempted to recreate the layout from a perspective that was shifted from the director's perspective. Crucially, as the matcher did not have visual access to the original layout (as both the director and the matcher were separated by a visual occluder) he could only rely on the instructions given by the director.

After reconstructing the layout, both the director and the matcher then individually completed a memory task, which revealed the specific reference frame they used in order to represent the object layout. While it is somewhat unsurprising that the matcher always represented the layout using an egocentric reference frame (given that this was the only perspective the matcher had experienced), there is evidence suggesting that the director also represented the matcher's perspective.

For example, Shelton and McNamara (2004) found that after having been explicitly instructed to describe the layout from the matcher's perspective, directors incorporated the matcher's perspective into their mental representations of the layout during the memory task. Furthermore, Galati, Michael, Mello, Greenauer, and Avraamides (2013) showed that explicit instructions about the partner's perspective were not necessary, and that the mere presence of a partner was sufficient for the partner's perspective to influence spatial memory. In contrast, Sjolund, Erdman, and Kelly (2014) found that regardless of the presence of a collaborative partner, directors exclusively remembered the spatial layout using an egocentric reference frame. Thus, the question remains under which conditions people are able to compute somebody else's VSP spontaneously, that is without being explicitly prompted to do so.

Spontaneous VSP-Taking

In most prior studies participants were explicitly asked to make judgments about the relative location of an object with respect to

the perspective of another agent (see Kessler & Thomson, 2010; Michelon & Zacks, 2006; Surtees et al., 2013). However, Tversky and Hard (2009) investigated how the presence of a person on a photograph exhibiting a different spatial orientation (namely, opposite of the participants, that is, in a 180° angle from their own position) affected people's verbal description of the spatial relations among an array of objects in the photographed scene (Tversky & Hard, 2009). Interestingly, the mere presence of a person in that scene indeed led a quarter of the participants to take that person's perspective and describe the locations of the objects from the other's rather than their own point of view (Tversky & Hard, 2009). Furthermore, when the photograph showed the person reaching out for an object and the experimenter phrased the question about the spatial relations of the depicted objects in terms of action (e.g., *In relation to the bottle where does he place the book?*), only 20% of the respondents stuck to their own point of view while the majority of them effectively adopted the other person's perspective to describe the scene in terms of his "right" and "left" (Tversky & Hard, 2009). On the one hand, these findings suggest that despite the complexity of having to cope with two contrasting spatial dimensions, participants nevertheless spontaneously integrated and applied the other person's VSP. On the other hand, this study was based on verbal reports which may have prompted explicit reasoning. Thus, it is still an open question in the literature whether people spontaneously adopt others' VSP outside of a communicative task. Importantly, the study by Tversky and Hard (2009) does point to the fact that perceiving another person performing an action might play a role for perspective-taking to occur.

Acting Together Increases Visuospatial Perspective-Taking

Certainly, in many situations we do not only share the same visual but, in addition, also the same task environment with other people. In order to successfully plan and coordinate our actions, we need to be able to flexibly integrate the perspectives of our coactors (cf. Creem-Regehr, Gagnon, Geuss, & Stefanucci, 2013). This prompts the assumption that in joint task settings, people should be particularly sensitive toward the respective perspectives of others. If this was the case, then one should find particularly pronounced instances of perspective-taking in joint task settings.

Supporting this claim, a study by Frischen, Loach, and Tipper (2009) showed that observing another person's actions effectively triggered the same selective attention processes (namely, inhibition of salient distractors) one finds when people perform an action on their own—the crucial difference being, that in the joint task scenario these processes occurred for an allocentric, rather than an egocentric frame of reference (Frischen et al., 2009).

Although this study gives an illustrative example of how the observation of action can effectively trigger a change of reference frames (see also Furlanetto, Cavallo, Manera, Tversky, & Becchio, 2013; Mazzarella, Hamilton, Trojano, Mastroiuro, & Conson, 2012), the exact relationship between VSP-taking and joint task performances remains unclear. For example, we do not know whether knowledge about the other person's task is sufficient to induce VSP-taking or whether it is necessary that one can directly observe (and receive feedback of) the other person's actions. Furthermore, how much does the other person need to be involved in the task in order to

spontaneously adopt her perspective—is it really necessary that the other is performing a task or could it be that the mere presence of another person exhibiting a different spatial orientation is already sufficient to trigger spontaneous VSP-taking? Finally, if there really is a tight connection between VSP-taking and performing actions together, as the study by Frischen et al. (2009) suggests, then how much of the other person’s task is actually represented while adopting her VSP and how does this impact on one’s own action planning?

Current Study

Taken together, there are still a number of open questions concerning the phenomenon of perspective-taking. First of all, it is still unclear whether people actually adopt others’ VSP outside of a communicative setting and, whether VSP-taking can also occur spontaneously. Second, is VSP-taking always detrimental to one’s task performance or can we find situations in which it is actually facilitative during joint task performances? Finally, there are already indications in the literature suggesting that spontaneous VSP-taking might be particularly pronounced in circumstances where another person performs actions (cf. Frischen, Loach, & Tipper, 2009; Tversky & Hard, 2009). However, this link between action and spontaneous VSP-taking has—to our knowledge—not yet been systematically tested.

The aim of this study was to address these issues in a systematic manner. We used a novel paradigm in a series of five experiments to investigate whether participants would spontaneously adopt a VSP that is not their own, and to test whether and how this would affect action planning. To this end, we needed a task where (a) there are two different VSPs, one of which is irrelevant for the participants’ task; and where (b) adopting the other’s VSP has a clear effect on action performance.

Throughout this study, we placed participants in a 90° angle to a confederate and asked them to perform an orthogonal stimulus-response (SR) compatibility task (cf. Craft & Simon, 1970; Simon, 1990) on a horizontally mounted (“table-like”) computer display (see Figure 1). Given the sitting position of the confederate and the participant, the stimuli could thus be perceived from two different VSPs—either along a vertical or along a horizontal axis. Measur-

ing responses according to the spatial position of the stimuli thereby allowed us to test effects of VSP-taking on action performance.

More specifically, the participant’s own perspective always coincided with the vertical axis, so that stimuli presented along this axis did not overlap with the participant’s horizontally arranged responses in terms of their spatial alignment. In contrast, the confederate’s perspective coincided with the horizontal axis, creating a spatial overlap between the arrangement of the stimuli and the participant’s responses. If participants showed a spatial compatibility effect in this context, this would provide clear evidence that they are performing the task relying on the confederate’s rather than their own VSP.

Experiment 1

The first experiment investigated whether participants spontaneously integrate the visuospatial perspective (VSP) of a confederate, while performing an orthogonal SR compatibility task. Participants sat in front of a horizontally arranged screen and in a 90° angle to a confederate and were instructed to respond with a right or a left button press to stimuli appearing at the top or the bottom of the screen, respectively (see Figure 1). From the confederate’s orientation, however, the stimuli appeared on the left and on the right side of the screen. Hence, we predicted that if participants adopted the confederate’s VSP, then they should show a spatial compatibility effect.

Method

Participants. Sixteen participants (mean age = 20.7 years, 11 women, 13 right-handed) signed up for this study and received gift vouchers for their participation. All were naïve to the purpose of the study, reported normal or corrected to normal vision, and signed informed consent prior to the experiment. All 16 participants met the inclusion criterion of having more than 90% successful trials within each experimental condition.

Stimuli and apparatus. The stimuli consisted of a rectangle (subtending 11.35° of visual angle horizontally and 6.53° vertically) in which there were three empty circles (each subtending 3.27° 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. These two types of stimuli were shown on a horizontally arranged 27” 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), which both the participant and the confederate placed on their lap. The button boxes were partially covered with a piece of carton so that out of the default array of seven buttons, only the ones used to respond (i.e., the buttons farthest to the left and right) were visible.

Design and procedure. Both the participant as well as a confederate, who sat in a 90° angle to the participant, sat as close as possible to the screen (viewing distance was \approx 35 cm). Throughout the entire study, the same young adult male acted as the confederate. Each trial started with the presentation of a fixation cross (subtending 1.31° of visual angle, presented in the center of the screen) for 350 ms. Subsequently, the screen turned blank

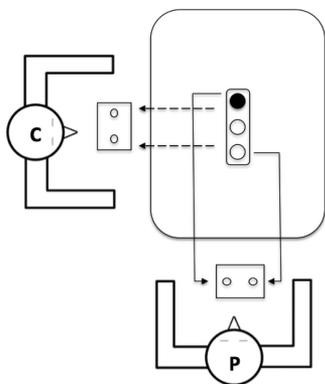


Figure 1. Experimental set-up for Experiment 1; participant (P) sits in a 90° angle to the confederate (C), example of the compatible condition. Dashed lines indicate the confederate’s mapping. Solid lines indicate the participant’s mapping.

for 100 ms after which, in a randomized manner, one of the two stimuli (top black disk vs. bottom black disk) was shown for 1,200 ms. Participants performed two conditions (*compatible* and *incompatible*), each containing 100 trials and were asked to respond as fast and as accurately as possible.

To establish different compatibility relations, we varied the sitting position of the confederate and the SR 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, while 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 condition (see Figure 1).

Before each of the two conditions, 10 practice trials familiarized the participants with the task. These were later excluded from the statistical analysis. Throughout both conditions the confederate, who sat in a 90° angle to the participant, was instructed to respond with a left button press if a black disk appeared 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. Both, the order of conditions and the position of the confederate (90° to the left vs. to the right of the participant) was counterbalanced across participants.

Data analysis. We collected data only from participants. Errors (i.e., trials in which the wrong button or no button at all was pressed) and reaction times (RTs) more than two standard deviations from each participant’s condition means were excluded from the analysis. Both the two condition means for correct response RTs for each participant as well as their errors were subjected to two separate two-tailed, paired-samples *t* tests.

Results

In this experiment, 2.7% of the trials were removed as errors and 4.8% were removed as outliers, leaving 92.5% of the raw data as correct response trials. Generally, the removal of these outliers did not result in changes of the significance patterns observed in this study. Comparing the number of errors in the compatible versus incompatible conditions did not reveal a statistically significant result, $t(15) < 1$, $p = .94$. The RT analysis revealed that on average, participants were significantly faster in the compatible ($M = 356$, $SE = 9.8$) than in the incompatible ($M = 374$, $SE = 13$) condition; $t(15) = -3.28$, $p = .005$, (see Figure 2). In order to test whether the sitting position of the confederate (to the left vs. to the right of the participants) or the order of conditions (starting with the compatible vs. the incompatible condition) had an influence on the results, a repeated measures ANOVA was conducted with compatibility as a within subjects factor and both sitting position of the confederate and order as between subjects factors. The results yielded only a main effect of compatibility, $F(1, 12) = 9.23$, $p = .01$, $\eta_p^2 = .435$, but no effect of sitting position, $F(1,$

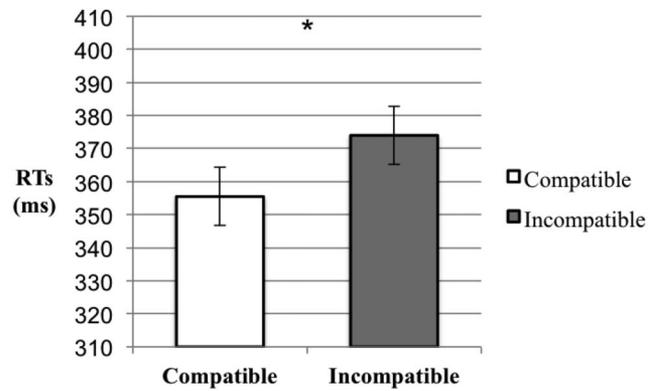


Figure 2. Mean RTs in the compatible and in the incompatible condition in Experiment 1. Error bars display within-subject confidence intervals according to Loftus and Masson (1994).

12) = 1.04, $p = .33$, $\eta_p^2 = .08$; order, $F(1, 12) < 1$, $p = .49$, $\eta_p^2 = .04$; or any interaction between them, all F s < 1 , p s $> .43$, $\eta_p^2 < .05$.

Discussion

From the participants’ point of view, there was no clear overlap between the stimulus dimension (which appeared on a vertical axis) and the response dimension (which was given on a horizontal axis). From the confederate’s perspective though, both the stimulus and the response dimension overlapped. Hence, the assigned SR mappings were compatible or incompatible only with respect to the confederate’s point of view.

The RTs of the participants showed a significant difference between the compatible and the incompatible condition. As this compatibility effect was independent of whether the confederate sat to the left or to the right of the participants, a SR compatibility (e.g., a general and exclusive performance advantage for the “up-right, down-left” mapping; see Cho & Proctor, 2003) cannot explain the pattern of these results. Instead, when the mapping of the participants concurred with the spatial orientation of the (left or right sitting) confederate, participants were significantly faster to respond compared with when the mapping did not concur with the confederate’s orientation. Importantly, the task did not require the participants to compute the perspective of the confederate. All in all, these results suggest that participants spontaneously adopted the visuospatial perspective of the confederate.

However, one could argue that the overt responses given by the confederate (who performed the SR task in close proximity to the participants) might have made his specific orientation to the stimuli very salient for the participants (cf. Frischen et al., 2009; Böckler, Knoblich, & Sebanz, 2011). In other words, it is possible that the confederate’s overtly given responses might have drawn participants’ attention toward his particular spatial orientation and hence, evoked the compatibility effect. Experiment 2 addressed whether having visual and auditory access to the confederate’s responses was necessary for spontaneous VSP taking to occur.

Experiment 2

Experiment 2 investigated the role of visual and auditory feedback exhibited by a coacting confederate on spontaneous VSP

taking. Previous studies have already shown that directly observing another person's actions leads people to adopt an allocentric frame of reference (Frischen et al., 2009). With regard to Experiment 1, it could therefore be argued that the overt responses of the confederate actually led the participants to pay more attention to his spatial orientation. Hence, being able to directly receive feedback from the confederate's actions might be a necessary precondition of spontaneously adopting another's VSP.

In contrast, another line of research indicates that explicit knowledge of another person's task is sufficient to form joint task representations, even if the actions are then covertly executed (see Sebanz, Knoblich, & Prinz, 2003; Tsai, Kuo, Hung, & Tzeng, 2008). If knowledge about the confederate's task in combination with knowledge about the location of his responses was sufficient to trigger a spontaneous adoption to his VSP in Experiment 1, then the previously found compatibility effect should persist regardless of whether or not feedback on the confederate's responses was available.

Method

Participants. Nineteen new participants (mean age = 23.94 years, nine women, all right-handed) signed up for this study and received gift vouchers for their participation. Three participants did not meet the inclusion criterion of having more than 90% successful trials within each experimental condition, leaving 16 participants (mean age = 22.25 years, eight women) 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 were identical to Experiment 1. The crucial difference between Experiment 1 and 2 was that in half of the experimental trials (the no-feedback condition) both the participants and the confederate wore ear-plugs (OHROPAX) as well as earmuffs (Earline MAX200 31020) so that their responses were inaudible. Furthermore, their response boxes were placed inside of cardboard boxes so that their hands were not visible.

Procedure. Participants performed two conditions (*feedback* and *no-feedback*). Each condition consisted of two blocks (*compatible* and *incompatible*). Each block contained 100 trials and participants were asked to respond as fast and as accurately as possible. The feedback condition was an exact replication of Experiment 1. Before the no-feedback condition, the experimenter placed the response boxes in the cardboard boxes and instructed both the participant and the confederate to put in ear-plugs and to put on the ear-muffs. Throughout both conditions, the participants and the confederate were instructed to perform the same tasks as in Experiment 1. As before, participants read through the instructions for their own and the confederate's task, which ensured that they knew about the correct response location in the no-feedback condition. Before each experimental block, 10 practice trials familiarized the participants with the task. These were later excluded from the statistical analysis.

The order of feedback conditions (feedback vs. no-feedback), the position of the confederate (90° to the left vs. to the right of the participant), as well as the order of compatibility conditions (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 two standard deviations from each participant's condition means were excluded from the 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 factor feedback (feedback vs. no-feedback) and compatibility (compatible vs. incompatible).

Results

In this experiment, 2.3% of the trials were removed as errors and 3.9% were removed as outliers, leaving 93.8% of the raw data as correct response trials.¹ The error analysis did not reveal any statistically significant results for feedback, $F(1, 15) < 1$, $p = .87$, $\eta_p^2 < .01$; compatibility, $F(1, 15) < 1$, $p = .87$, $\eta_p^2 < .01$; or the interaction between the two, $F(1, 15) = 1.31$, $p = .27$, $\eta_p^2 < .08$.

The RT analysis revealed a significant main effect of compatibility, $F(1, 15) = 14.32$, $p = .002$, $\eta_p^2 = .488$ with RTs being faster during compatible than during incompatible trials (see Figure 3). There was neither a main effect of feedback, $F(1, 15) < 1$, $p = .52$, $\eta_p^2 = .02$, nor an interaction between compatibility and feedback, $F(1, 15) < 1$, $p = .99$, $\eta_p^2 < .01$.

Discussion

The main effect of compatibility indicates that participants were always faster to respond when their assigned mapping concurred with the spatial orientation of the confederate, regardless of whether they received visual or auditory feedback on the confederate's responses. Thus, this suggests that knowledge about the confederate's task together with knowledge about the location of his responses was sufficient to trigger a spontaneous adoption of the confederate's VSP. At the same time, this experiment provided evidence for VSP-taking in a context where (un-)intentional coordination of actions or entrainment (cf. Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007; Schmidt & Richardson, 2008) could not have occurred because participants and confederates could not perceive each other's actions. The results of this experiment therefore indicate that entrainment is not a necessary factor for the observed VSP-taking effect to occur.

However, other studies suggested that the mere (passive) presence of another person already suffices to change the way in which stimuli are perceived with respect to that person's frame of reference (see Costantini, Committeri, & Sinigaglia, 2011; Tversky & Hard, 2009). Looking for the minimal conditions under which spontaneous VSP taking is exhibited, this leads to the question, whether VSP taking in the present task is relying on another person's actions at all. Maybe the diverging point of view of the confederate could have already been sufficient for participants to switch to the confederate's frame of reference. This question was addressed in Experiment 3.

Experiment 3

Experiment 3 investigated, whether the confederate's differing orientation to the stimuli was already sufficient for participants to

¹ The removal of outliers did not result in any changes of the significance patterns observed in this experiment.

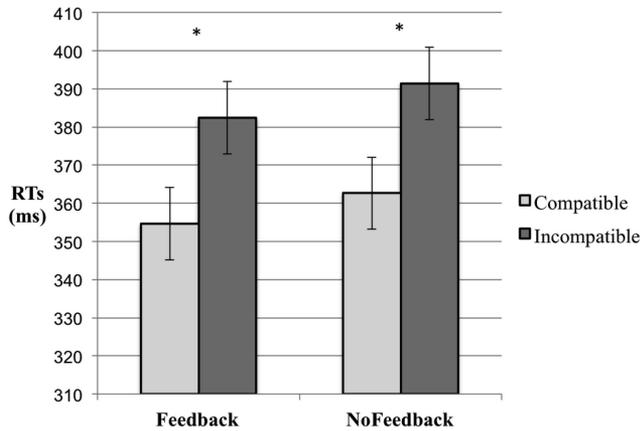


Figure 3. Mean RTs in the feedback and in the no-feedback condition in Experiment 2. Error bars display within-subject confidence intervals according to Loftus and Masson (1994).

adopt his VSP. Previous studies suggest that the presence of a *passive agent* suffices to change the way in which humans perceive spatial relations among objects (Tversky & Hard, 2009) as well as their surrounding action space (Costantini et al., 2011). On the contrary, other research has shown that knowledge about the *intentional actions* of another agent is crucial in order to simulate his actions and thereby establish interpersonal links (Atmaca, Sebanz, Prinz, & Knoblich, 2008; Sebanz et al., 2003; Zwicker, 2009).

So far, the previous experiments cannot disentangle whether the task performance of the confederate was actually necessary in order for spontaneous VSP taking to occur or whether the mere presence of another agent exhibiting a different frame of reference might have already been sufficient to trigger the same effect. We hypothesized that if the diverging perspective alone sufficed to trigger spontaneous VSP taking, then it should not matter whether the confederate actually performed the SR compatibility task. If, on the other hand, the task performance of the confederate was necessary in order to evoke spontaneous VSP, then the effect should be restricted to those conditions, in which the confederate actually performs the compatibility task alongside the participants.

Method

Participants. Twenty-five new participants (mean age = 22.6 years, 13 women, 23 right-handed) signed up for this study and received gift vouchers for their participation. One participant did not meet the inclusion criterion of having more than 90% successful trials within each experimental condition, leaving 24 participants (mean age = 22.54 years, 12 women, 22 right-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. These were identical to Experiment 1.

Procedure. Participants performed two conditions (*other-active* and *other-passive*) with two blocks (*compatible* and *incompatible*), respectively. Each block contained 100 trials and participants were asked to respond as fast and as accurately as possible. While the other-active condition was an exact replication of Ex-

periment 1, in the other-passive condition the confederate was instructed not to respond but just to observe 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 (other-active, vs. other-passive), the position of the confederate (90° to the left vs. to the right of the participant), as well as the order of compatibility conditions (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 two standard deviations from each participant's condition means were excluded from the analysis. 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 role of confederate (active vs. passive) and compatibility (compatible vs. incompatible).

Results

In this experiment, 2.5% of the trials were removed as errors and 4% were removed as outliers, leaving 93.5% of the raw data as correct response trials.² The error analysis revealed a significant main effect of role of confederate, $F(1, 23) = 15.9, p < .01, \eta_p^2 = .4$, showing that participants made more errors when the confederate was active ($M = 3.5\%$ errors) than when the confederate was passive ($M = 1.6\%$ errors). Neither the main effect of compatibility, $F(1, 23) < 1, p = .83, \eta_p^2 < .01$, nor the interaction between role of other and compatibility, $F(1, 23) < 1, p < .77, \eta_p^2 < .01$, was significant.

The RT analysis revealed a significant interaction between role of confederate and compatibility, $F(1, 23) = 5.1, p = .03, \eta_p^2 = .18$. In post hoc analyses, pairwise comparisons showed a significant difference in RTs between the compatible ($M = 338, SD = 32$) and incompatible ($M = 355, SD = 38$) blocks only in the “active,” $t(23) = -4.62, p < .01$, two-tailed, but not in the “passive” condition, $t(23) < 1, p = .85$ (see Figure 4). Furthermore, those trials in which the confederate was active but the participants' mapping was incompatible did not statistically differ from both compatible, $t(23) < 1, p = .4$, and incompatible trials, $t(23) < 1, p = .35$, in which the confederate was passive. Put differently, the data shows that—compared with all the other three conditions—participants had a particular speed advantage for the compatible trials, in which the confederate was active (compatible active vs. compatible passive: $t(23) = -2.47, p = .021$; compatible active vs. incompatible passive: $t(23) = -3.05, p = .006$). In addition, there was a marginally significant main effect of role of confederate, $F(1, 23) = 3.88, p = .06, \eta_p^2 = .14$, with faster RTs when the confederate was active, and a tendency for compatibility, $F(1, 23) = 3.21, p = .09, \eta_p^2 = .12$.

Discussion

Most importantly, Experiment 3 elicited a significant interaction effect between the factors role of other and compatibility. Only during the other-active condition were participants significantly faster to respond to compatible versus incompatible trials. This

² The removal of outliers did not result in any changes of the significance patterns observed in this experiment.

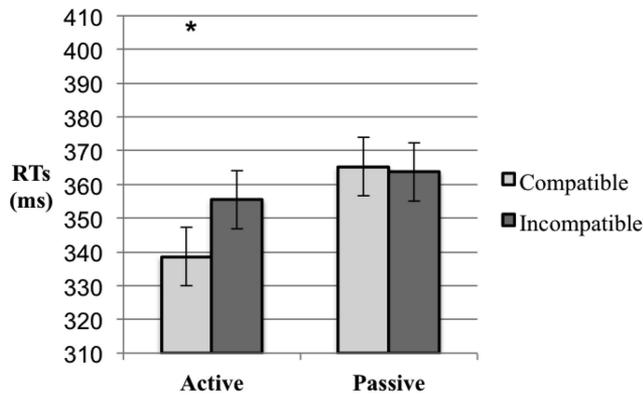


Figure 4. Mean RTs in the other-active and in the other-passive condition in Experiment 3. Error bars display within-subject confidence intervals according to Loftus and Masson (1994).

pattern of results suggest that spontaneous VSP taking crucially relies on the confederate being perceived as an intentional coactor (cf. Sebanz et al., 2003; Zwickel, 2009) and that the mere presence of a passive confederate is not sufficient in order to induce a spontaneous adoption of his point of view.

Interestingly, the post hoc comparisons indicated that, compared with the other conditions, participants were significantly faster only during compatible trials and thus, that VSP-taking might have actually facilitated their task performance. We will return to this point in the General Discussion.

The marginally significant main effect of role of confederate ($p = .06$) in RTs, together with the significant main effect of role of confederate ($p < .01$) in terms of errors suggest that there was a speed-accuracy trade-off during the blocks where the confederate was active. However, the fact that participants were faster and made more errors in the other-active condition does not explain the compatibility effect in this condition.

The results suggest that knowledge about the confederate's task (Experiment 2) together with the actual task performance of the confederate (Experiment 3) is necessary to trigger spontaneous VSP taking. This indicates that the underlying mechanism leading to spontaneous VSP taking might not only hinge on the other's visuospatial perspective but—to some degree—also on a representation of the other person's task.

In order to find out exactly what role the confederate's task played and how much of his task was actually represented by the participants, we conducted Experiment 4. One confound that needed to be ruled out was that in all the experiments thus far, the responding hands of the participant and the confederate always changed together with the assigned mappings. That is, in compatible conditions, both of them always used the same responding hand and in incompatible conditions they always used different hands on any given trial. According to the task corepresentation account from the literature on joint action, people form representations of each other's stimulus-response mappings when acting next to each other (see Butterfill & Sebanz, 2011; Sebanz & Knoblich, 2009; Sebanz, Knoblich, & Prinz, 2005). In line with this account, one could therefore argue that the participants in the above experiments might have corepresented the confederate's exact SR mappings, which in turn could have caused the compat-

ibility effect. In other words, the knowledge about when the confederate needed to push which button with which hand could have sped participants up during compatible trials, in which they had to execute the *same actions* (e.g., both of them needed to push the "left" button with their left hand), and slowed them down during incompatible trials, in which they had to execute *opposite actions* (e.g., one needed to push the left, while the other needed to push the right button). Importantly, such a process could be independent of the actual VSP of the confederate. This alternative explanation was examined in Experiment 4.

Experiment 4

In the previous experiment it was shown that the confederate needed to perform a task alongside the participants in order for spontaneous VSP to occur. Experiment 4 investigated exactly what role the confederate's task played and how much of his task was actually represented by the participants.

The rationale behind this experiment was as follows: If participants actually represented the confederate's task in terms of SR rules (Sebanz et al., 2005), seeing a stimulus that requires a particular response from the confederate would activate a representation of this response. Regardless of the visuospatial orientation of the confederate, they should thus be faster when their responding hands coincided with the confederate's, and slower when their responding hands differed.

In contrast, one could also contend that the presence of an active confederate was already sufficient to modulate participants' frame of reference with respect to the stimuli (cf. Mazzarella et al., 2012). Hence, if exact knowledge about the other's task in terms of SR rules was not necessary and instead, the presence of a coacting confederate already sufficed to trigger spontaneous VSP taking, then one would expect the previously found effect to be independent of whether the same or different hands were used to respond.

Method

Participants. Nineteen new participants (mean age = 24.32 years, 11 women, 18 right-handed) signed up for this study and received gift vouchers for their participation. Three participants did not meet the inclusion criterion of having more than 90% successful trials within each experimental condition, leaving 16 participants (mean age = 23.1 years, 10 women, 15 right-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. These were identical to Experiment 1.

Procedure. Participants performed two conditions (*same hands* and *different hands*) with two blocks (*compatible* and *incompatible*), respectively. Each block contained 100 trials and participants were asked to respond as fast and as accurately as possible. Their task was identical to Experiment 1. However, while in the previous experiments the task of the confederate never changed (that is, he was always assigned to a congruent mapping throughout the entire experiment) it now switched; in half the trials, the confederate performed a congruent mapping (i.e., when a stimulus appeared on his right-hand side, he needed to respond with a right button press and vice versa), in the other half, he was now assigned to an incongruent mapping (i.e., when a stimulus

appeared on his right-hand side, he needed to respond with a left button press and vice versa). The instructions for both the confederate and the participant resulted in half the trials being performed with their same hands (hence, the *same hands* condition) and the other half being performed with different hands (i.e., the *different hands condition*, see Figure 5). Before each condition, 10 practice trials familiarized the participants with the task. These were later excluded from the statistical analysis.

The order of conditions (same hands vs. different hands), the position of the confederate (90° to the left vs. to the right of the participant), as well as the order of compatibility conditions (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 two standard deviations from each participant's condition means were excluded from the 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 hands (same vs. different) and compatibility (compatible vs. incompatible).

Results

In this experiment, 2.5% of the trials were removed as errors and 3.4% were removed as outliers, leaving 94.1% of the raw data as correct response trials.³ The error analysis did not reveal any statistically significant results for hands, $F(1, 15) < 1, p = .99, \eta_p^2 < .01$; compatibility, $F(1, 15) < 1, p = .56, \eta_p^2 = .02$; or the interaction between the two, $F(1, 15) < 1, p = .89, \eta_p^2 < .01$.

The RT analysis revealed a significant main effect of compatibility, $F(1, 15) = 30.22, p < .001, \eta_p^2 = .67$, with RTs being generally faster during compatible than during incompatible trials (see Figure 6). Furthermore, there was a significant interaction between compatibility and hands, $F(1, 15) = 5.65, p = .03, \eta_p^2 = .27$. The difference score between incompatible and compatible trials was significantly higher in the same ($M = 32.97, SD = 21.94$), compared with the different hands condition ($M = 17.54, SD = 23.05$), $t(15) = 2.37, p = .03$. Post hoc two-tailed t tests then revealed a significant compatibility effect between compatible and

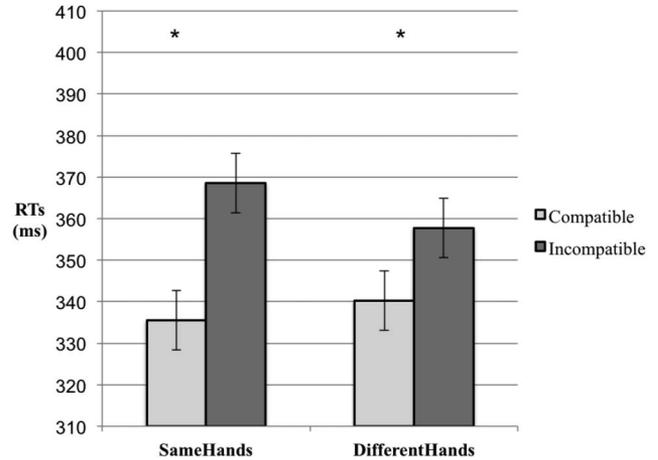


Figure 6. Mean RTs in the same-hands and in the different-hands condition in Experiment 4. Error bars display within-subject confidence intervals according to Loftus and Masson (1994).

incompatible trials both in the same hands, $t(15) = -6.01, p < .01$, as well as in the different hands condition, $t(15) = -3.04, p < .01$. In addition, participants were slower on incompatible trials, in which they used the same hand as the confederate ($M = 368, SD = 41$), compared to incompatible trials, in which the two used different hands ($M = 357, SD = 38$). However, this comparison was only marginally significant; $t(15) = 2.04, p = .06$. Finally, there was no main effect of hands, $F(1, 15) < 1, p = .34, \eta_p^2 = .06$, suggesting that participants were not overall faster or slower when responding with the same or different hand as the confederate.

Discussion

Experiment 4 investigated whether responding with the same or with a different hand as the confederate affected the participants' compatibility effect. The results showed that the compatibility effect did not depend on but was influenced by the relation between the responding hands. The significant main effect of compatibility together with the absence of a significant main effect of hands suggests that regardless of whether participants had to respond with the same or different hands as the confederate, they were always significantly faster to respond during compatible compared with incompatible trials.

Indicated by the interaction effect, we also found evidence suggesting that participants' responses were not completely independent from the responses given by the confederate. More specifically, it seems as if using the same hands during incompatible trials particularly hampered participants' responses. One could hypothesize that during this condition, the mismatch between the VSP of the confederate and the required SR mapping was particularly salient because the confederate simultaneously also responded in an incongruent manner. However, as the group comparison was only marginally significant, this remains a tentative conjecture.

Taken together with the results from the previous experiment our findings suggest that participants' spontaneous adoption of the

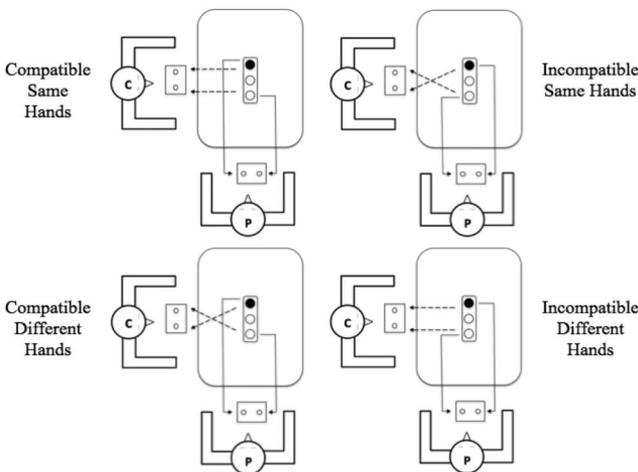


Figure 5. Overview of experimental set-up in Experiment 4.

³ The removal of outliers did not result in any changes of the significance patterns observed in this experiment.

confederate's VSP did rely on the confederate performing a task next to them (Experiment 3) while it did not rely on an exhaustive representation of the confederate's task in terms of SR mappings (Experiment 4). This raises the question whether *any task* performed by the confederate can trigger the mechanism underlying spontaneous VSP taking or whether it has to be a *spatially matching one*, that is, a task in which the stimulus and the response dimension overlap (cf. Kornblum, Hasbroucq, & Osman, 1990).

Experiment 5

In the previous experiments it was shown that participants reliably adopted a confederate's VSP, as long as the confederate was performing a SR task (cf. Experiment 3) but regardless of whether this SR task was congruent (cf. Experiment 1–3) or incongruent for the confederate (cf. Experiment 4) in terms of the hands used for responding.

Experiment 5 investigated whether a spatially neutral SR arrangement (that is, neither congruent nor incongruent, e.g., vertically presented stimuli in combination with laterally arranged responses, cf. Kornblum et al., 1990) performed by the confederate is already sufficient to trigger spontaneous VSP taking. This allowed us to find out more about the underlying mechanism of the spontaneous adoption of another's VSP.

Theoretically, there can be two competing explanations for the compatibility effect found in the previous experiments. On the one hand, it could have been the case that participants adopted the confederate's point of view (seeing the stimuli as "left and right" rather than "up and down") as well as the spatial dimension of his responses—which also entailed a "left" and a "right" dimension. As a result this would allow for an overlap between SR dimensions and hence, lead to the compatibility effect. On the other hand, one could claim that participants adopted the point of view of the confederate but disregarded his response dimension and instead "superimposed" their own response dimension. As the participants' own responses were also given laterally (i.e., as left and right), this could have also lead to a conflict between the stimulus and the response dimension and hence, to a compatibility effect.

To disentangle these two alternatives, we rotated the confederate's response dimension so that also from his point of view, it no longer overlapped with the stimulus dimension (see Figure 7). The rationale behind this manipulation was the following: If participants adopted both the point of view *and* the spatial response dimension of the confederate, then the compatibility effect should disappear once the confederate responded orthogonally (that is with an "up" and a "down" button press) to the stimuli. Alternatively, if participants took the point of view of the confederate but retained their own response dimension (that is, perceive the responses as "left" and "right"), then the compatibility effect should persist regardless of the confederate's response dimension.

Method

Participants. Nineteen new participants (mean age = 21 years, eight women, all right-handed) signed up for this study and received gift vouchers for their participation. Three participants did not meet the inclusion criterion of having more than 90% successful trials within each experimental condition, leaving 16 participants (mean age = 21.88 years, eight women, all right-

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, apparatus, and design. The stimuli were identical to Experiment 1. The only difference in the apparatus was that the confederate's button box was rotated 90° on his lap so that instead of being located left and right, the two response buttons were now oriented up and down with respect to the confederate. Hence, there was no longer an overlap between the spatial dimension of the stimuli (appearing to the left and right of the confederate) and the spatial dimension of the confederate's responses (now requiring an "up" and "down" response). Thus, for both, the participants and the confederate, the stimulus and response dimensions were now orthogonal to each other (see Figure 7).

Procedure. Participants performed two conditions (*same hands* and *different hands*) 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 as accurately as possible. The confederate was instructed to respond with an "up" button press whenever a stimulus appeared to his right and a "down" button press whenever a stimulus appeared to his left side, respectively.

In order to control for same and different hand responses between the participants and the confederate, the confederate performed half the trials with his right hand on top and the other half with his left hand on top. The instructions for both the confederate and the participant then lead to half the trials being performed with their same hands (hence, the *same hands* condition) and the other half with different hands (i.e., the *different hands condition*).⁴ Before each condition, 10 practice trials familiarized the participants with the task. These were later excluded from the statistical analysis.

The order of conditions (same hands vs. different hands), the sitting 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 two standard deviations from each participant's condition means were excluded from the 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 hands (same vs. different) and compatibility (compatible vs. incompatible).

Results

In this experiment, 2.17% of the trials were removed as errors and 4.01% were removed as outliers, leaving 93.82% of the raw data as correct response trials.⁵ The error analysis did not reveal any statistically significant results for hands, $F(1, 15) < 1, p = .94$,

⁴ If, for instance, the confederate sat to the left of the participant and was instructed to have his left hand on top, while the participant was instructed to respond according to the "up-right, down-left" mapping, they would then use the same hands in this block.

⁵ The removal of outliers did not result in any changes of the significance patterns observed in this experiment.

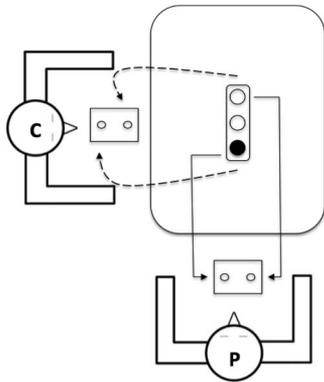


Figure 7. Experimental set-up for Experiment 5; participant (P) sits in a 90° angle to the confederate (C), example of the incompatible and different hands condition.

$\eta_p^2 < .01$; compatibility, $F(1, 15) < 1, p = .67, \eta_p^2 = .01$; or the interaction between the two, $F(1, 15) = 1.38, p = .26, \eta_p^2 = .08$.

The RT analysis revealed a significant main effect of compatibility, $F(1, 15) = 16.51, p = .001, \eta_p^2 = .524$, with RTs being faster in compatible, than in incompatible trials (see Figure 8). There was neither a significant main effect of hands, $F(1, 15) < 1, p = .84, \eta_p^2 < .01$, nor a significant interaction effect, $F(1, 15) < 1, p = .71, \eta_p^2 = .01$.

Discussion

The significant main effect of compatibility indicates that participants were generally faster to respond during compatible compared to incompatible trials, regardless of whether the confederate was assigned to a spatially neutral (that is, neither congruent nor incongruent) task and regardless of whether the two were instructed to use the same or different hands to respond.

The results suggest that while it is necessary that the confederate is involved in a task in order for spontaneous VSP taking to occur (cf. Experiment 3), it is sufficient if this task is a neutral SR task (cf. Experiment 5) rather than a spatially matching one (cf. Experiment 1, 2, and 4). Taken together, these results also shed light on the underlying mechanism of spontaneous VSP taking. More specifically, they bolster the claim that participants adopted the confederate's point of view while upholding their own response dimension. In other words, it seems as if participants perceived the stimuli in a similar manner as the confederate did (namely, as "left and right" rather than from their own point of view: "up and down"), while they disregarded the way in which the confederate's responses were orientated. Instead, they seem to have superimposed their own response dimension (i.e., "left and right") onto the confederate's ("up and down"). Coding both the stimuli and the necessary responses as "left and right" created a dimensional overlap which could have resulted in the observed compatibility effect.

General Discussion

The aim of this study was to investigate the underlying factors as well as boundary conditions that could lead to the spontaneous adoption of another person's VSP during social interactions. In a

nutshell, we found that, throughout the course of five experiments, participants reliably adopted the VSP of a coacting confederate who sat in a 90° angle to the participants, as long as he was perceived as an intentionally acting agent.

More specifically, while performing an orthogonally arranged SR task (i.e., stimuli appeared vertically, while responses were given laterally), participants reliably showed a compatibility effect that corresponded to the confederate's visuospatial perspective. For example, if the confederate sat to the right of the participants, they were significantly faster to respond to an "up-right, down-left" mapping, compared with "up-left, down-right" and vice versa if the confederate sat to the left of the participants (Experiment 1). As the confederate performed a congruent SR task (that is, responding to a left stimulus with a left button press and vice versa) in close proximity to the participant in Experiment 1, we then investigated whether perceiving the confederate acting constituted a boundary condition for the effect to occur.

Experiment 2 demonstrated that regardless of receiving auditory and visual feedback from the confederate, participants again showed the compatibility effect. This result suggests that knowledge about the confederate's task was sufficient for the participants to adopt his VSP. This led to the question whether the confederate needed to perform a task at all or whether his passive presence together with his diverging orientation in relation to the stimuli was enough to trigger spontaneous VSP-taking. Crucially, in Experiment 3 we found that it was necessary that the confederate performed the task in order for the participants to adopt his VSP and hence, that the mere presence of a passive confederate was not sufficient.

While the active versus passive role of the confederate was crucial, Experiment 4 revealed that spontaneous VSP-taking was largely independent of the overlap of the specific SR mappings between the two actors. Put differently, while encoding the stimulus relative to the VSP of the confederate, participants were not overall faster or slower to respond when using the same or different hands as the confederate.

Finally, Experiment 5 showed that participants adopted their confederate's VSP even if the confederate performed an orthogo-

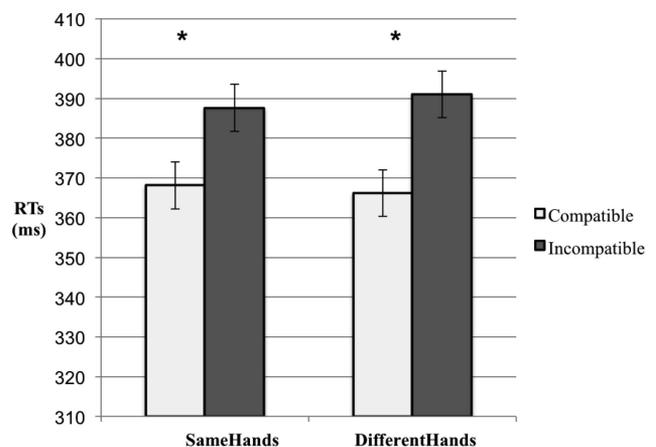


Figure 8. Mean RTs in the same-hands and in the different-hands condition in Experiment 5. Error bars display within-subject confidence intervals according to Loftus and Masson (1994).

nal SR task. Thus, it seems as if during the task participants adopted the point of view of the confederate (i.e., perceiving the stimuli as “left and right” rather than from their own point of view, that is, as “up and down”), while retaining their own (that is, “left and right”) response dimension.

Taken together, the findings of the present study therefore show that participants spontaneously adopted a differing VSP while performing a SR task when there was an intentionally acting agent alongside of them. Importantly, the activity of the confederate constituted a boundary condition for spontaneous VSP-taking to occur. Hence, rather than reflecting an automatic process which was activated whenever there was another agent having a differing perspective on the stimuli, our data suggests that participants instead required sufficient information to believe that the other person was actively involved in the task in order to adopt his VSP.

Spontaneous VSP-taking in our study was tightly connected to the partner’s actions (cf. Creem-Regehr et al., 2013). While our findings are therefore in line with other studies highlighting the link between action and perspective-taking (Furlanetto et al., 2013; Mazarella et al., 2012; Tversky & Hard, 2009; and see Costantini et al., 2011) they also show, for the first time, that action-related VSP-taking can take place even outside of a communicative setting. Furthermore, our results demonstrate an effect of VSP on one’s own action planning, extending previous studies that have reported effects of VSP-taking in tasks where participants made judgments about the location of objects or had to indicate what could be seen from a particular perspective.

Even though perspective-taking in our study occurred spontaneously, it could be argued that diverging from one’s own VSP in order to adopt somebody else’s must nevertheless require extensive processing (Dumontheil et al., 2010; Keysar et al., 2000; Keysar et al., 2003; Mattan et al., 2015). This would mean that the found compatibility effect was most likely driven by an interference effect during the adoption of the confederate’s perspective. If the adoption to another person’s perspective is already effortful, then having to deal with an incompatible SR arrangement on top of that must be reflected in particularly increased response latencies on incompatible trials. However, a closer look at the results of Experiment 3 points to a different direction. The post hoc comparisons of Experiment 3 revealed that the interaction effect between role of other and compatibility was driven by participants being significantly faster to respond during *compatible* trials in which the confederate was *active* compared to each of the other three conditions. Rather than causing interference and increased response latencies, it therefore seems as if adopting the VSP of an active confederate could effectively *facilitate* the processing of the task. While it would be illustrative to explore how the confederate’s presence changes the performance compared to an individual baseline, one could argue that the passive condition is a more convincing baseline, as it generally rules out possible social facilitation effects. Thus, one might conjecture that instances of spontaneous VSP-taking in our study may have been driven by facilitative processes. Such mechanisms might be particularly useful in situations where multiple agents have constantly changing perspectives but nevertheless need to coordinate their actions under time pressure (e.g., passing a ball during a soccer match).

Finally, when there could not be any intentional or unintentional interpersonal coordination of actions (as in Experiment 2), we did not find evidence that the lack of these coordination processes

diminished the compatibility effect. However, it may be interesting to investigate in future studies whether instructing participants to act in synchrony with the confederate could further boost the effects shown in our study.

We believe that the mechanism underlying the observed effects involves a switch from an egocentric to an allocentric reference frame (Mazarella et al., 2012). Switching reference frames might have been prompted by the left-right-dimension of the participants’ response locations. Experiment 5 indicated that the effect is driven by an overlap between the spatial dimension of the participants’ responses (left-right) and the spatial dimension of the stimuli from an allocentric perspective (also left-right) because the effect persisted regardless of the particular spatial arrangement of the confederate’s responses. In future studies it would therefore be interesting to determine whether the spatial dimension of the participants’ responses is a necessary factor in order to trigger VSP-taking.

In conclusion, the findings of the present study show that participants spontaneously adopted a differing VSP while performing a SR task, given there was an intentionally acting agent alongside of them. In consequence, the current study extends our prior understanding on perspective-taking in two ways. To our knowledge, these are the first results showing that humans adopt another person’s VSP by all respects *spontaneously*; that is, in the absence of a communicative context and without being prompted to do so. Second, our data suggests that, given the right circumstances, spontaneous VSP-taking might effectively facilitate and speed up spatial alignment processes accruing from dynamic interactions in multiagent environments.

References

- Atmaca, S., Sebanz, N., Prinz, W., & Knoblich, G. (2008). Action co-representation: The joint SNARC effect. *Social Neuroscience*, *3*, 410–420. <http://dx.doi.org/10.1080/17470910801900908>
- 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>
- Bratman, M. E. (1992). Shared cooperative activity. *The Philosophical Review*, *101*, 327–341. <http://dx.doi.org/10.2307/2185537>
- Butterfill, S. A., & Sebanz, N. (2011). Editorial: Joint action: What is shared? *Review of Philosophy and Psychology*, *2*, 137–146. <http://dx.doi.org/10.1007/s13164-011-0062-3>
- Cho, Y. S., & Proctor, R. W. (2003). Stimulus and response representations underlying orthogonal stimulus-response compatibility effects. *Psychonomic Bulletin & Review*, *10*, 45–73.
- Costantini, M., Committeri, G., & Sinigaglia, C. (2011). Ready both to your and to my hands: Mapping the action space of others. *PLoS ONE*, *6*, e17923. <http://dx.doi.org/10.1371/journal.pone.0017923>
- 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>
- Dumontheil, I., Apperly, I. A., & Blakemore, S. J. (2010). Online usage of theory of mind continues to develop in late adolescence. *Developmental*

- Science*, 13, 331–338. <http://dx.doi.org/10.1111/j.1467-7687.2009.00888.x>
- 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., 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>
- Galati, A., Michael, C., Mello, C., Greenauer, N. M., & Avraamides, M. N. (2013). The conversational partner's perspective affects spatial memory and descriptions. *Journal of Memory and Language*, 68, 140–159. <http://dx.doi.org/10.1016/j.jml.2012.10.001>
- 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>
- Keysar, B., Barr, D. J., Balin, J. A., & Brauner, J. S. (2000). Taking perspective in conversation: The role of mutual knowledge in comprehension. *Psychological Science*, 11, 32–38. <http://dx.doi.org/10.1111/1467-9280.00211>
- Keysar, B., Lin, S., & Barr, D. J. (2003). Limits on theory of mind use in adults. *Cognition*, 89, 25–41. [http://dx.doi.org/10.1016/S0010-0277\(03\)00064-7](http://dx.doi.org/10.1016/S0010-0277(03)00064-7)
- Kornblum, S., Hasbroucq, T., & Osman, A. (1990). Dimensional overlap: Cognitive basis for stimulus-response compatibility—A model and taxonomy. *Psychological Review*, 97, 253–270. <http://dx.doi.org/10.1037/0033-295X.97.2.253>
- Loftus, G. R., & Masson, M. E. (1994). Using confidence intervals in within-subject designs. *Psychonomic Bulletin & Review*, 1, 476–490.
- Mattan, B., Quinn, K. A., Apperly, I. A., Sui, J., & Rotshtein, P. (2015). Is it always me first? Effects of self-tagging on third-person perspective-taking. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 41, 1100–1117. <http://dx.doi.org/10.1037/xlm0000078>
- Mazzarella, E., Hamilton, A., Trojano, L., Mastroiuro, 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>
- Michelon, P., & Zacks, J. M. (2006). Two kinds of visual perspective taking. *Perception & Psychophysics*, 68, 327–337. <http://dx.doi.org/10.3758/BF03193680>
- Perner, J., Brandl, J. L., & Garnham, A. (2003). What is a perspective problem? Developmental issues in belief ascription and dual identity. *Facta Philosophica*, 5, 355–378.
- 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
- Richardson, M. J., Marsh, K. L., Isenhower, R. W., Goodman, J. R., & Schmidt, R. C. (2007). Rocking together: Dynamics of intentional and unintentional interpersonal coordination. *Human Movement Science*, 26, 867–891. <http://dx.doi.org/10.1016/j.humov.2007.07.002>
- 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>
- Schmidt, R. C., & Richardson, M. J. (2008). Dynamics of interpersonal coordination. In A. Fuchs & V. K. Jirsa (Eds.), *Coordination: Neural, behavioral and social dynamics* (pp. 281–308). Berlin, Germany: Springer Berlin Heidelberg. http://dx.doi.org/10.1007/978-3-540-74479-5_14
- Schober, M. F. (1995). Speakers, addressees, and frames of reference: Whose effort is minimized in conversations about location? *Discourse Processes*, 20, 219–247. <http://dx.doi.org/10.1080/01638539509544939>
- Sebanz, N., & Knoblich, G. (2009). Prediction in joint action: What, when, and where. *Topics in Cognitive Science*, 1, 353–367. <http://dx.doi.org/10.1111/j.1756-8765.2009.01024.x>
- Sebanz, N., Knoblich, G., & Prinz, W. (2003). Representing others' actions: Just like one's own? *Cognition*, 88, B11–B21. [http://dx.doi.org/10.1016/S0010-0277\(03\)00043-X](http://dx.doi.org/10.1016/S0010-0277(03)00043-X)
- Sebanz, N., Knoblich, G., & Prinz, W. (2005). How two share a task: Corepresenting stimulus-response mappings. *Journal of Experimental Psychology: Human Perception and Performance*, 31, 1234–1246. <http://dx.doi.org/10.1037/0096-1523.31.6.1234>
- Shelton, A. L., & McNamara, T. P. (2004). Spatial memory and perspective taking. *Memory & Cognition*, 32, 416–426. <http://dx.doi.org/10.3758/BF03195835>
- 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](http://dx.doi.org/10.1016/S0166-4115(08)61218-2)
- Sjölund, L. A., Erdman, M., & Kelly, J. W. (2014). Collaborative inhibition in spatial memory retrieval. *Memory & Cognition*, 42, 876–885. <http://dx.doi.org/10.3758/s13421-014-0407-0>
- 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>
- Tsai, C. C., Kuo, W. J., Hung, D. L., & Tzeng, O. J. (2008). Action co-representation is tuned to other humans. *Journal of Cognitive Neuroscience*, 20, 2015–2024. <http://dx.doi.org/10.1162/jocn.2008.20144>
- 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>
- Vogeley, K., & Fink, G. R. (2003). Neural correlates of the first-person perspective. *Trends in Cognitive Sciences*, 7, 38–42. [http://dx.doi.org/10.1016/S1364-6613\(02\)00003-7](http://dx.doi.org/10.1016/S1364-6613(02)00003-7)
- Zwicker, 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 April 20, 2015

Revision received September 1, 2015

Accepted September 1, 2015 ■