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When Far Becomes Near: Perspective Taking Induces Social Remapping of Spatial Relations

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Abstracts

On many occasions, people spontaneously or deliberately take the perspective of a person facing them rather than their own perspective. How is this done? Using a spatial perspective task in which participants were asked to identify objects at specific locations, we found that self-perspective judgments were faster for objects presented to the right, rather than the left, and for objects presented closer to the participants' own bodies. Strikingly, taking the opposing perspective of another person led to a reversal (i.e., remapping) of these effects, with reference to the other person's position (Experiment 1). A remapping of spatial relations was also observed when an empty chair replaced the other person (Experiment 2), but not when access to the other viewpoint was blocked (Experiment 3). Thus, when the spatial scene allows a physically feasible but opposing point of view, people respond as if their own bodies were in that place. Imagination can thus overcome perception.

Keywords

spatial perspective taking, remapping, recomputing, spatial relations

How do people represent the location of things in space? In contrast to the uniform extension of Newtonian space, a space delineated by experiential relations is used in everyday life: Things appear "either nearer or farther, above or below, right or left" (Husserl, 1952/1989, p. 158). A person who is alone computes these relations with reference to his or her own position in space, that is, using an *egocentric frame of reference*. For example, someone sitting alone at a table might say that a cup on the opposite side is "far from me, from my body" (Husserl, 1952/1989, p. 166). In richer physical and social environments, however, other people often feature prominently, and a person may spontaneously refer *spatial relations* to another person's perspective. When people are asked to tell someone else where something is located, for example, they typically answer from the other person's viewpoint (e.g., "on your left"; Mainwaring, Tversky, Ohgishi, & Schiano, 2003; Schober, 1993). Moreover, even when not communicating, observers may spontaneously describe spatial relations from the opposing spatial perspective of another person (Tversky & Hard, 2009), a tendency that strengthens when that other person's intention is ambiguous (Furlanetto, Cavallo, Manera, Tversky, & Becchio, 2013). Thus, when an observer is facing another person, "near" can become near to that other person but far from the observer, and "to the right" can refer to that other person's right but to the observer's left. How can people take the conflicting spatial perspective of another person facing them rather than their own very real perspective?[1]

One possibility is that people do not set aside their own spatial perspective when adopting another person's but instead use it as a starting point to recompute the relations of the objects from that other perspective (*recomputing* hypothesis). That is, people could initially compute the spatial relations from their own perspective and only subsequently adjust (i.e., recompute) those relations to accommodate differences between their own and the other perspective, for example, by reversing left and right (Epley, Keysar, Van Boven, & Gilovich, 2004; Shelton & McNamara, 1997, 2001).

Another hypothesis is that people take the perspective of an opposing person by remapping the locations of the objects to an *altercentric frame of reference*, that is, by mentally placing themselves in the other person's position (*remapping* hypothesis). Although remapping might seem surprising, indirect evidence for it comes from patients who exhibit unilateral spatial neglect. Neglect patients typically ignore objects on their left when asked to respond from their own perspective. Recently, however, it has been demonstrated that they are able to recover previously omitted items when responding from the perspective of a person seated opposite them (Becchio, Del Giudice, Dal Monte, Latini-Corazzini, & Pia, 2013). Thus, it seems that they might update (i.e., remap) object locations to an intact altercentric frame of reference. Whether remapping also supports spatial perspective taking in typical brains, however, is yet to be determined. Could people remap spatial relations to another perspective rather than recompute them?

This is the first question we addressed in the present study. In a simple task, we asked participants to report the left/right spatial location of a target (an apple) from their own perspective and from the perspective of a human avatar facing them. The apple was either close to the participants but far from the avatar or close to the avatar but far from the participants. Prior research suggests that with an egocentric frame of reference, relative times to identify objects at specific locations depend on body asymmetries, asymmetries in the world, and action possibilities (Franklin & Tversky, 1990). Right-handers, for instance, are faster to process objects on the right than objects on the left (Furlanetto, Gallace, Ansuini, & Becchio, 2014; Olson & Laxar, 1973). Moreover, reaction times (RTs) are generally proportional to the distance of the target, increasing as distance of the to-be-located objects increases (Sun & Wang, 2010). We took advantage of these effects to investigate how spatial relations are mapped from self- and other-perspectives. We reasoned that if participants recomputed spatial relations, then regardless of the perspective they were asked to take, they would respond faster when the apple was to their right and closer to them. Alternatively, if participants remapped the spatial relations by mentally envisioning the scene from the avatar's perspective, their judgments would be faster on self-perspective trials when the apple was to the right (rather than to the left) and closer to the participant but faster on other-perspective trials when the apple was to the right and closer to the avatar.

We tested these predictions in Experiment 1. After finding evidence for remapping from the perspective of a human avatar sitting at the opposite end of a table, we conducted two further experiments that were attempts to break the remapping, that is, to find its limits. In Experiment 2, we replaced the human avatar with an empty chair. In Experiment 3, we positioned the table against the wall and placed two bookcases at the sides of the table, to discourage access to the opposite perspective.

Experiment 1

On each trial of Experiment 1, participants viewed a scene such as the one depicted in Figure 1. They were asked to judge whether the apple was to the left or right from their own perspective and from that of the human avatar seated at the opposite end of the table. RTs served as a proxy for how difficult self-perspective and other-perspective judgments were.

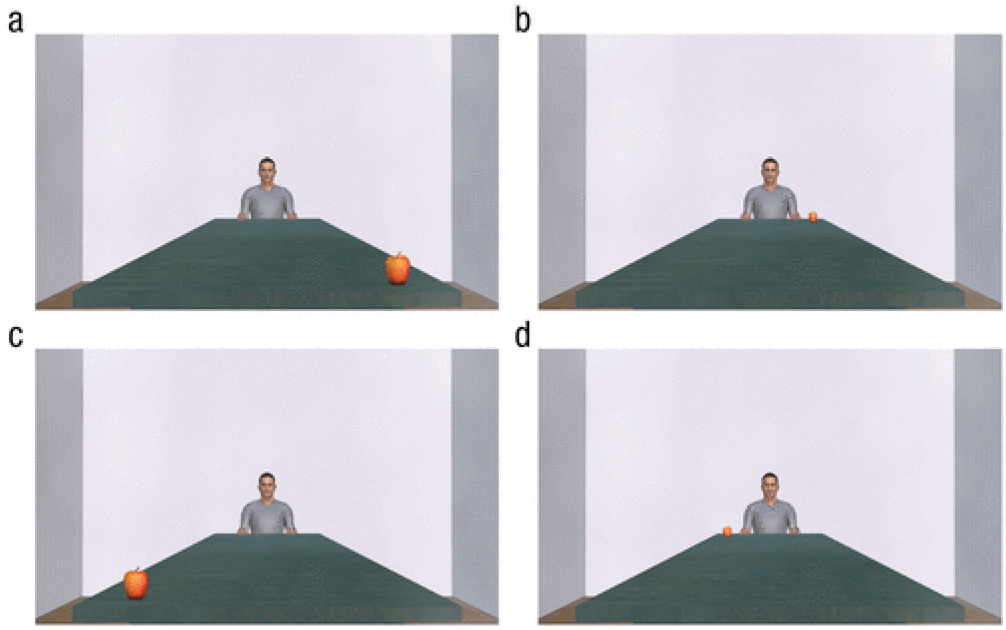

Fig. 1. Experimental stimuli for Experiment 1. The stimuli were pictures showing a virtual room that contained a rectangular table with an apple on it. A male human avatar was seated at one end of the table, opposite the participant. The apple could be in any one of four positions: (a) right-near, (b) right-far, (c) left-near, or (d) left-far. Participants were asked to report verbally whether the apple was on the "left" or "right" from either their own or the avatar's perspective.

Method

Participants

We based our sample size on previously published studies testing spatial perspective taking (Kessler & Thomson, 2010). Prior to data collection, we decided to test 27 participants. All 27 (13 women, 14 men; mean age = 23.8 years, range = 19–36) were healthy and right-handed, had normal or corrected-to-normal visual acuity, and were naive to the purpose of the experiment. None had a history of neurological, major medical, or psychiatric disorders. The experimental procedures were approved by the ethics committee of the University of Turin and were carried out in accordance with the principles of the revised Helsinki Declaration (World Medical Association, 2013). Written informed consent was obtained from each participant prior to the experiment.

Stimuli

The experimental stimuli consisted of pictures showing a 2-D room that contained a rectangular table with an apple on it. The field of view of the virtual camera was set to match the field of view of a person seated at one end of the table. In all stimuli, a male human avatar was seated at the opposite end of the table, with hands resting on the table. The apple was presented in one of four positions: The right-near position was on the right side of the table close to the participant, near enough to be virtually reachable for him or her (Fig. 1a); the right-far position was on the right side of the table far from the participant, in close proximity to the avatar, so as to be virtually reachable by the avatar (Fig. 1b); the left-near position was on the left side of the table close to the participant (Fig. 1c); and the left-far position was on the left side of the table far from the participant (Fig. 1d). The room, the human avatar, and the apple were created with the 3-D animation software Poser 9 (SmithMicro Software, Aliso Viejo, CA).

Procedure

Participants were seated in a comfortable chair in front of a 17-in. computer screen, at a viewing distance of 50 cm. They were asked to keep their arms uncrossed for the entire duration of the experiment (see Furlanetto et al., 2014). Each trial began with a green fixation cross presented on a black background for 500 ms. The word “You” or “Avatar” then appeared for 1,000 ms, instructing participants to take, respectively, either their own perspective (self-perspective trials) or the avatar’s perspective (other-perspective trials). Then the picture of the virtual room appeared and remained on-screen until a response was given or 3,000 ms had elapsed. Participants were instructed to report verbally whether the apple was on the “left” or “right” from the given perspective. The participants’ vocal RTs were recorded. In addition, their responses were recorded manually by the experimenter using a wireless keyboard. Participants completed 120 trials (60 self-perspective and 60 other-perspective trials) divided into four blocks. The order of self- and other-perspective trials was pseudorandomized to ensure that participants were not asked to answer from the same perspective more than three times in a row. The experiment took approximately 30 min. The timing and ordering of the trials, as well as the collection of vocal RTs, were controlled by E-Prime software (Version 2.0; Schneider, Eschman, & Zuccolotto, 2012).

Data analysis

Trials in which vocal RTs deviated more than 2 *SD* from the mean of the corresponding experimental condition were discarded as outliers (4.30%), as were trials in which participants responded incorrectly (7.83%). In addition, 2 participants were excluded from the group analysis because their RTs deviated more than 2 *SD* from the group average. Vocal RTs were submitted to a 2 × 4 repeated measures analysis of variance (ANOVA) with perspective (self, other) and position (right-near, right-far, left-near, left-far) as within-subjects factors. A significance threshold of $p < .05$ was set for all statistical tests, and Holm-Sidak correction was applied for pairwise comparisons. For the sake of clarity, the levels of the position variable are defined here with respect to the participant’s perspective, regardless of the perspective the participant was asked to take (self, other).

Results

As found in previous work (Furlanetto et al., 2014), participants were more accurate when they responded from their own perspective ($M = .945$, 95% confidence interval, or CI = [.929, .961]) than when they responded from the avatar’s perspective ($M = .895$, 95% CI = [.866, .925]), $t(24) = 3.58$, $p = .002$. The 2 × 4 ANOVA on vocal RTs yielded a significant main effect of perspective, $F(1, 24) = 46.18$, $p < .001$, $\eta_p^2 = .658$; RTs were slower on other-perspective trials ($M = 791.24$ ms, 95% CI = [703.31, 879.17]) than on self-perspective trials ($M = 676.15$ ms, 95% CI = [612.41, 739.88]). There was also a main effect of position, $F(1, 24) = 3.42$, $p = .022$, $\eta_p^2 = .125$. These effects were moderated by a significant interaction between perspective and position, $F(3, 72) = 19.108$, $p < .001$, $\eta_p^2 = .443$. On self-perspective trials, there was a significant advantage when the apple was positioned on the right side (right-near and right-far: $M = 627.74$ ms, 95% CI = [568.21, 687.27]) rather than on the left side (left-near and left-far: $M = 724.55$ ms, 95% CI = [653.02, 796.09]), $F(1, 24) = 37.12$, $p < .001$, $\eta_p^2 = .607$ (Fig. 2, left graph), and also when it was near (right-near and left-near: $M = 650.29$ ms, 95% CI = [591.20, 709.39]) rather than far (right-far and left-far: $M = 701.99$ ms, 95% CI = [631.43, 772.56]), $F(1, 24) = 16.39$, $p < .001$, $\eta_p^2 = .406$ (Fig. 2, right graph). Crucially, and in line with the remapping hypothesis, these mappings were reversed when participants responded from the perspective of the human avatar. On other-perspective trials, RTs were significantly faster when the apple appeared on the left side (left-near and left-far: $M = 756.09$ ms, 95% CI = [686.45, 843.75]) rather than on the right side (right-near and right-far: $M = 817.39$ ms, 95% CI = [717.06, 917.72]), $F(1, 24) = 7.38$, $p = .012$, $\eta_p^2 = .235$ (Fig. 2, left graph), and when it was far (right-far and left-far: $M = 778.05$ ms, 95% CI = [693.21, 862.89]) rather than near (right-near and left-near: $M = 804.43$ ms, 95% CI = [712.26, 896.60]), $F(1, 24) = 6.43$, $p = .018$, $\eta_p^2 = .211$ (Fig. 2, right graph).

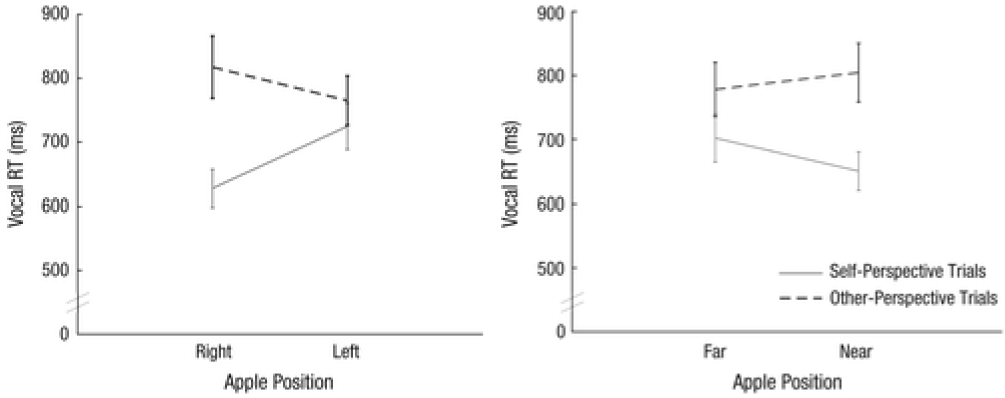

Fig. 2. Results from Experiment 1: mean vocal reaction time (RT) on self- and other-perspective trials as a function of left/right position of the apple (left graph) and near/far position of the apple (right graph). For both perspectives, apple positions are reported from the participants' perspective. Error bars represent ±1 *SE*.

These results suggest that participants remapped the spatial relations of the scene when responding from the perspective of the human avatar. The question we posed in Experiment 2 was whether the presence of another person is critical for such remapping to occur.

Experiment 2

To test whether remapping is driven by the presence of a human body, we replaced the avatar in half of the trials of Experiment 2 with an empty chair and asked participants to respond from the perspective of a person who would be seated in the chair. If a human body is critical for producing the reversal of left/right and near/far mappings, then remapping would be limited to the avatar session. Alternatively, if participants were able to mentally locate themselves at the position of the empty chair, then their RTs would reveal remapping in both the avatar and the chair sessions.

Method

Participants

Twenty-seven healthy new volunteers (14 women, 13 men; mean age = 24.2 years, range = 19–32) with no history of neurological problems took part in Experiment 2. All were right-handed and had normal or corrected-to-normal vision. As in Experiment 1, participants were naive to the purpose of the experiment and provided written informed consent.

Stimuli, procedure, and data analysis

Stimuli, experimental procedures, and data-analysis procedures were the same as in Experiment 1, except that on half of the trials, the human avatar was replaced with an empty chair with armrests, which occupied approximately the same area as the avatar (Fig. 3a). On these trials, participants were instructed to respond from their own perspective (self-perspective trials) or from the perspective of a person who would be seated in the chair at the opposite side of the table (other-perspective trials). Avatar and chair trials were presented in separate sessions, each session containing 120 trials (60 self-perspective and 60 other-perspective trials) divided into four blocks. As in Experiment 1, the order of self- and other-perspective trials was pseudorandomized to ensure that participants were not asked to answer from the same perspective more than three times in a row. The order of the sessions (avatar, chair) was counterbalanced across participants. Trials in which vocal RTs deviated more than 2 *SD* from the mean of each experimental condition were discarded as outliers (4.77%), as were trials in which participants responded incorrectly (4.20%). In addition, 2 participants were excluded from the group analysis because their RT values deviated more than 2 *SD* from the group average.

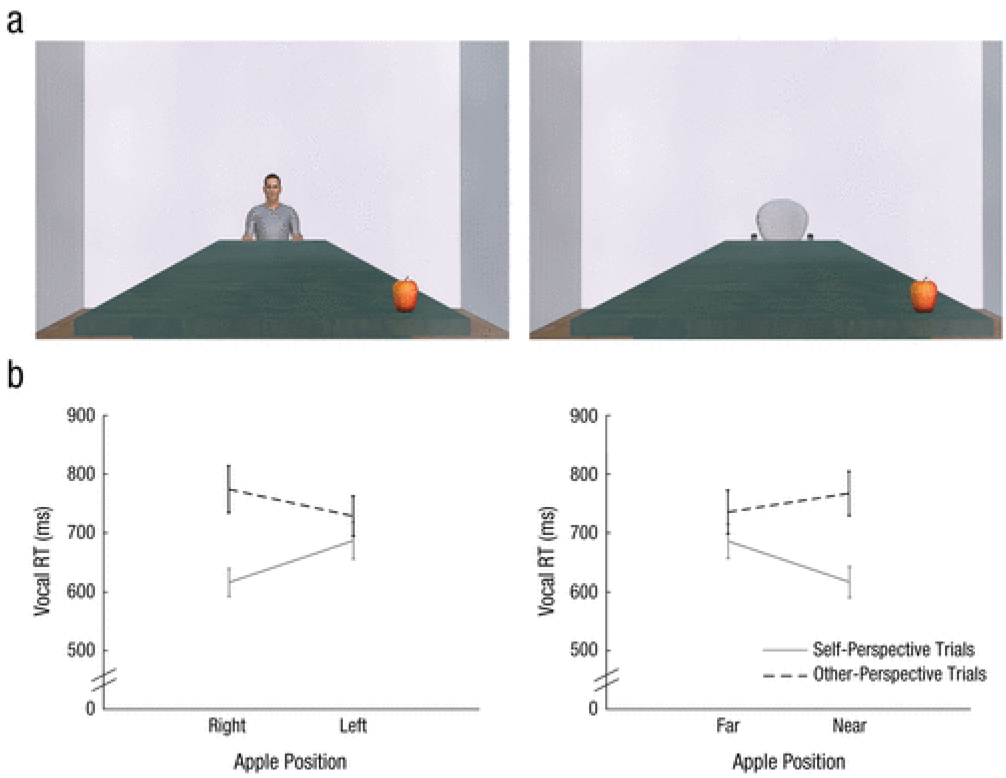

Fig. 3. Example stimuli and results from Experiment 2. Participants completed the same task as in Experiment 1, but on half the trials, an empty chair replaced the human avatar (a). The graphs (b) show mean vocal reaction time (RT) on self- and other-perspective trials as a function of left/right position of the apple (left graph) and near/far position of the apple (right graph). For both perspectives, apple positions are reported from the participants' perspective. Error bars represent ±1 *SE*.

Results

Participants were more accurate when they responded from their own perspective rather than the other perspective in both the avatar session (self-perspective: *M* = .979, 95% CI = [.968, .989]; other-perspective: *M* = .951, 95% CI = [.929, .974]), $t(24) = 2.502$, $p = .020$, and the chair session (self-perspective: *M* = .970, 95% CI = [.957, .983]; other-perspective: *M* = .932, 95% CI = [.902, .962]), $t(24) = 2.735$, $p = .012$. The 2 (session: avatar, chair) × 2 (perspective: self, other) × 4 (position: near-right, near-left, far-right, far-left) ANOVA on vocal RTs yielded a significant main effect of perspective, $F(1, 24) = 37.626$, $p < .001$, $\eta_p^2 = .611$, with slower RTs on other-perspective trials (*M* = 751.23 ms, 95% CI = [682.54, 819.93]) than on self-perspective trials (*M* = 650.85 ms, 95% CI = [603.35, 698.36]). Additionally, the ANOVA showed a main effect of position, $F(3, 72) = 5.763$, $p = .001$, $\eta_p^2 = .194$, and a significant interaction between perspective and position, $F(3, 72) = 31.772$, $p < .001$, $\eta_p^2 = .570$.

Preplanned contrasts showed that on self-perspective trials, RTs were significantly faster when the apple was positioned on the right side (right-near and right-far: *M* = 615.07 ms, 95% CI = [574.92, 655.22]) rather than on the left side (left-near and left-far: *M* = 686.96 ms, 95% CI = [629.60, 744.32]), $F(1, 24) = 28.40$, $p < .001$, $\eta_p^2 = .542$ (Fig. 3b, left graph), and also when it was near (right-near and left-near: *M* = 616.26 ms, 95% CI = [569.96, 662.56]) rather than far (right-far and left-far: *M* = 686.23 ms, 95% CI = [635.70, 736.76]), $F(1, 24) = 74.24$, $p < .001$, $\eta_p^2 = .756$ (Fig. 3b, right graph). In contrast, on other-perspective trials, RTs were significantly faster when the apple was positioned on the left side (left-near and left-far: *M* = 728.82 ms, 95% CI = [665.52, 792.12]) rather than on the right side (right-near and right-far: *M* = 774.10 ms, 95% CI = [697.99, 850.20]), $F(1, 24) = 14.91$, $p = .002$, $\eta_p^2 = .383$ (Fig. 3b, left graph) and when it was far (right-far and left-far: *M* = 734.81 ms, 95% CI = [666.31, 803.31]) rather than near (right-near and left-near: *M* = 767.19 ms, 95% CI = [697.22, 837.16]), $F(1, 24) = 12.46$, $p = .002$, $\eta_p^2 = .342$ (Fig. 3b, right graph).

Contrary to the hypothesis that the presence of a human body is critical for the reversal of body mapping, the three-way interaction between session, perspective, and position was not significant, $F(3, 72) = 0.447$, $p = .720$, $\eta_p^2 = .018$. This indicates that remapping is observed both when participants respond from the perspective of a human avatar and when they respond from the perspective of an empty chair. Thus, remapping does not require the presence of a human avatar but simply the possibility of a human perspective. Would removing that possibility lead participants to recompute rather than remap spatial relations? We tested this question in Experiment 3.

Experiment 3

In the attempt to further specify the conditions for remapping, in this experiment, we positioned the table against the opposing wall and placed bookcases on either side of the table (Fig. 4a). Thus, in these scenes, there was no room for a person to occupy a position on the other side of the table. Remapping effects in these scenes disappeared.

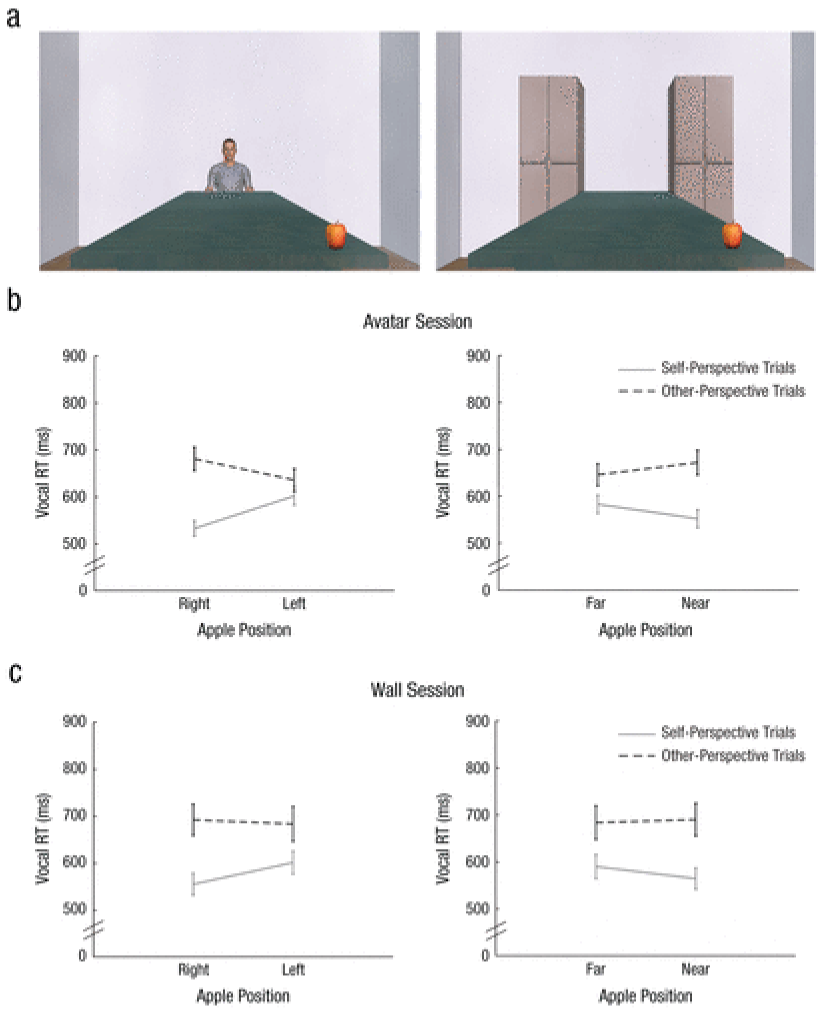

Fig. 4. Example stimuli and results from Experiment 3. Participants completed the same task as in Experiment 2, except that the chair session was replaced with the wall session, in which the table was positioned against the wall and flanked by two bookcases (a). The graphs show mean vocal reaction time (RT) on self- and other-perspective trials as a function of left/right position of the apple (left graphs) and near/far position of the apple (right graphs), separately for the (b) avatar session and (c) wall session. For both perspectives, apple positions are reported from the participants' perspective. Error bars represent ±1 *SE*.

Method

Participants

Twenty-six healthy new volunteers (16 women, 10 men; mean age = 22.9 years, range = 19–27) with no history of neurological problems took part in the experiment. All were right-handed and had normal or corrected-to-normal vision. As in Experiments 1 and 2, participants were naive to the purpose of the experiment and provided written informed consent; information about the experimental hypothesis was given only at the end of the experiment.

Stimuli, procedure, and data analysis

Stimuli, experimental procedures, and data-analysis procedures were the same as in Experiment 2, except that the chair session was replaced with the wall session, in which the table was positioned against the wall of the room between two office bookcases, as depicted in Figure 4a. In wall trials, participants were instructed to respond from their own perspective (self-perspective trials) or from the perspective of a person who would be located at the opposite end of the table (other-perspective trials). As in Experiment 1, trials in which vocal RTs deviated more than 2 *SD* from the mean of the corresponding condition were discarded as outliers (4.44%), as were trials in which participants responded incorrectly (7.31%). In addition, 2 participants were excluded from the group analysis because their RT values deviated more than 2 *SD* from the group average.

Results

Participants were more accurate when they responded from their own perspective rather than the other perspective in both the avatar session (self-perspective: *M* = .963, 95% CI = [.950, .975]; other-perspective: *M* = .892, 95% CI = [.846, .939]), $t(23) = 3.670$, $p = .001$, and the wall session (self-perspective: *M* = .958, 95% CI = [.941, .975]; other-perspective: *M* = .895, 95% CI = [.851, .940]), $t(23) = 3.043$, $p = .006$. The 2 (session: avatar, wall) × 2 (perspective: self, other) × 4 (position: near-right, near-left, far-right, far-left) ANOVA on vocal RTs yielded a main effect of perspective, $F(1, 23) = 71.194$, $p < .001$, $\eta_p^2 = .756$, with slower RTs on other-perspective trials (*M* = 672.75 ms, 95% CI = [533.77, 610.72]) than on self-perspective trials (*M* = 572.25 ms, 95% CI = [617.03, 728.46]), and a main effect of position, $F(3, 69) = 2.915$, $p = .040$, $\eta_p^2 = .112$. The ANOVA also revealed a significant interaction between perspective and position, $F(3, 69) = 22.276$, $p < .001$, $\eta_p^2 = .492$, and a significant three-way interaction between session, perspective, and position, $F(3, 69) = 3.349$, $p = .024$, $\eta_p^2 = .127$.

Preplanned contrasts conducted on this interaction showed that on self-perspective trials, RTs were significantly faster when the apple was positioned on the right side rather than on the left side in both the avatar session (right-near and right-far: *M* = 532.03 ms, 95% CI = [498.74, 565.32]; left-near and left-far: *M* = 602.03 ms, 95% CI = [562.57, 641.50]), $F(1, 24) = 42.18$, $p < .001$, $\eta_p^2 = .647$, and the wall session (right-near and right-far: *M* = 554.22 ms, 95% CI = [506.09, 602.34]; left-near and left-far: *M* = 600.51 ms, 95% CI = [551.10, 649.92]), $F(1, 24) = 10.71$, $p = .003$, $\eta_p^2 = .318$. Moreover, RTs were also faster when the apple was near rather than far in both the avatar session (right-near and left-near: *M* = 551.79 ms, 95% CI = [517.01, 586.57]; right-far and left-far: *M* = 583.29 ms, 95% CI = [547.26, 619.32]), $F(1, 24) = 23.05$, $p < .001$, $\eta_p^2 = .500$, and the wall session (right-near and left-near: *M* = 564.83 ms, 95% CI = [520.08, 609.58]; right-far and left-far: *M* = 589.95 ms, 95% CI = [540.33, 639.56]), $F(1, 24) = 7.31$, $p = .013$, $\eta_p^2 = .241$.

Central to our hypothesis, on other-perspective trials, a reversal of the effects of target position was observed only in the avatar session, with faster RTs when the apple was on the left side (left-near and left-far: *M* = 636.07 ms, 95% CI = [587.11, 685.03]) rather than on the right side (right-near and right-far: *M* = 681.18 ms, 95% CI = [629.57, 732.79]), $F(1, 24) = 12.31$, $p = .002$, $\eta_p^2 = .349$ (Fig. 4b, left graph), and when it was far (right-far and left-far: *M* = 645.41 ms, 95% CI = [597.90, 692.92]) rather than near (right-near and left-near: *M* = 672.01 ms, 95% CI = [620.00, 724.01], $F(1, 24) = 6.01$, $p = .022$, $\eta_p^2 = .207$ (Fig. 4b, right graph). For wall trials, RTs were not significantly slower when the apple was on the left side (left-near and left-far: *M* = 682.55 ms, 95% CI = [606.43, 758.68]) rather than on the right side (right-near and right-far: *M* = 691.70 ms, 95% CI = [622.82, 760.57]), $F(1, 24) = 0.34$, $p = .567$, $\eta_p^2 = .014$ (Fig. 4c, left graph). Similarly, no difference in RTs was observed between far positions (right-far and left-far: *M* = 683.76 ms, 95% CI = [610.75, 756.77]) and near positions (right-near and left-near: *M* = 690.03 ms, 95% CI = [620.22, 759.85]), $F(1, 24) = 0.27$, $p = .609$, $\eta_p^2 = .012$ (Fig. 4c, right graph).

General Discussion

How do people represent space from the perspective of another person? In an egocentric frame of reference, people's RTs to identify objects at specific locations vary with respect to their own bodies. The critical new finding reported here is that this pattern changes when one takes another person's perspective. When responding from their own viewpoint, right-handed participants responded faster when the object was closer to and to the right of them. In contrast, when responding from the viewpoint of a human avatar seated facing them, participants responded faster when the object was closer to and to the right of the avatar (Experiment 1). A similar pattern of RTs was observed when an empty chair replaced the human avatar at the opposite side of the table (Experiment 2), but, notably, not when the table was against the wall (Experiment 3), which suggests that, in the latter case, participants found it difficult to mentally place themselves in the opposite viewpoint.

These data are consistent with a dynamic change in the encoding of spatial relations, such that when taking another person's perspective, participants remapped spatial relations to the other's position (remapping hypothesis). Could these effects depend on the task instruction, that is, to judge the left/right location of a target object from one's own or another's perspective? If so, we would have expected a reversal of left/right mapping but not of near/far mapping. This is because participants were never asked to judge the distance of the target object. The finding that taking the perspective of another person also reversed the usual asymmetry between near and far positions supports the hypothesis that spatial relations were remapped independently of the specific task requirements.

A second finding is that the mapping of spatial relations reversed when other-perspective judgments were anchored both to a human avatar and to an empty chair. It may seem surprising that remapping also occurred in the absence of a body. The presence of a body anchor has been proposed to be necessary for embodiment of a third-person perspective (Gardner, Brazier, Edmonds, & Gronholm, 2013; Gianelli, Farnè, Salemme, Jeannerod, & Roy, 2011), and there is evidence that bodily features modulate spontaneous perspective taking (Tversky & Hard, 2009). However, these results may be related to understanding another person's action rather than to the presence of a body (Furlanetto et al., 2013; Zwickel, 2009). People adopt the perspective of another person who acts or is in the position to act on objects (Tversky & Hard, 2009) and may do so even in the absence of a human body provided that the scene is designed for human action. Observers are relatively good at perceiving the potential for action for themselves and others with respect to object properties (Creem-Regehr, Gagnon, Geuss, & Stefanucci, 2013). An empty chair affords the possibility of sitting (Gibson, 1979). As the philosopher George Herbert Mead (1962) put it, "the chair invites us to sit down" (p. 280). Thus, it is not surprising that in Experiment 2, participants relocated themselves mentally to the chair.

To find the limits of remapping, in Experiment 3, we replicated Experiment 2 with a crucial change: We removed the chair and moved the table against the wall. This was critical to demonstrate that remapping not only appears when it should, but also disappears when it should. Indeed, if remapping depends on the possibility of occupying the other position, then it should disappear when there is no room to locate oneself at that position. As expected, body remapping did not occur. How did participants report spatial relations in this case? If participants computed the opposing perspective by adjusting from their own perspective (recomputing hypothesis), we would have expected the usual advantage for right and near positions observed on self-perspective trials. This did not occur. We found no differences between left and right positions and between near and far positions. This pattern of RTs suggests that participants mapped object locations into a neutral space. This result is reminiscent of work by Franklin, Tversky, and Coon (1992) showing that participants asked to respond from two different perspectives alternately can take an overhead perspective of the entire scene. It is thus possible that because they could not relocate to the opposite perspective, in Experiment 3, they adopted an external perspective. Although the present study cannot confirm or disprove this hypothesis, the availability of such an alternative strategy makes the results of Experiments 1 and 2 even more striking, as it suggests that unless access to the other perspective is prevented, remapping is more natural than adopting a neutral perspective.

At a neural level, these findings may be related to the discovery that premotor and parietal cortices contain neuronal subpopulations that encode the space both near one's own hand and near another person's hand (Brozzoli, Gentile, Bergouignan, & Ehrsson, 2013; Ishida, Nakajima, Inase, & Murata, 2010). Intriguingly, both these areas have been implicated in taking the perspective of another person (David et al., 2006; Kaiser et al., 2008). It is thus tempting to speculate that these substrates may support the dynamic remapping of spatial relations to an altercentric frame of reference during perspective taking.

It remains to be determined exactly what features of the scene drive remapping in the absence of a human other. Recent studies suggest that agency and "agentic" features are critical for nonhuman entities (such as arrows) to elicit spontaneous visual perspective processing (Furlanetto, Becchio, Samson, & Apperly, 2016; Santiesteban, Catmur, Hopkins, Bird, & Heyes, 2014; Schurz et al., 2015). Determining whether these or other features (e.g., the strength with which a scene evokes a view-dependent action representation) govern remapping in spatial perspective taking will guide researchers toward uncovering the mechanisms that allow people routinely to overcome their own position in space.

Conclusions

Overall, our results provide a notable demonstration of the dynamic modification of spatial representations induced by perspective taking. It is already well known that people can assume spatial perspectives different from their own. Our results demonstrate how people rapidly adjust their mapping of spatial relations to a new viewpoint, which leads to a remapping of object locations with reference to the other perspective.

Spatial remapping has been extensively documented in relation to tool use (Holmes & Spence, 2004; Legrand, Brozzoli, Rossetti, & Farnè, 2007; Serino, Bassolino, Farnè, & Làdavas, 2007). Our results show that, as when spatial recalibration is induced by tool use, spatial relations are recalibrated when people overcome their actual spatial perspective to mentally locate their body in another place (Pezzulo, Iodice, Ferraina, & Kessler, 2013). This suggests that spatial representations not only plastically change following active tool use, but also dynamically change when people take another person's viewpoint.

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Notes

1.Perspective taking, including the visual, spatial, and mental or conceptual varieties, has meant different things to different communities. Here, we refer to *spatial perspective taking*, that is, the ability to understand where something is located relative to someone else (Surtees, Apperly, & Samson, 2013).