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BRIEF REPORT

Social effects on reference frame selection

Jonathan W. Kelly[1] · Kristi A. Costabile[1] · Lucia A. Cherep[1]

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Abstract

The presence of another person in a spatial scene has been shown to induce spontaneous perspective taking. This investigation presents two experiments exploring whether the presence of another person affects reference frame selection when representing object locations in memory. Participants studied objects from one view and later performed judgments of relative direction, which tested retrieval of the remembered layout from several imagined perspectives. Without another person in the scene during learning, participants selected a reference frame aligned with the studied view. The mere presence of the experimenter at a different perspective during learning did not affect reference frame selection. Requiring participants to process object locations from the experimenter's view during learning led to the selection of a reference frame aligned with the experimenter. However, the same effect also occurred when participants processed object locations from the perspective of a wooden box. In sum, the presence of another person during learning did not affect reference frame selection, and participants adopted a nonegocentric reference frame whether the nonegocentric perspective was occupied by a person or an object.

Keywords Spatial cognition · Spatial memory · Social cognition

Location is a relative concept (e.g., the mall is on the north side of town) which must be defined in the context of a reference frame. Spatial memory research indicates that reference frames characterizing long-term spatial memory are established during encoding, and subsequent retrieval is easiest when it occurs from perspectives parallel to reference frame axes. Research on memory for room-sized layouts has identified several cues known to influence reference frame selection. For example, Shelton and McNamara (2001) asked participants to learn a layout of objects arranged on the floor and subsequently evaluated reference frame organization by asking participants to perform judgments of relative direction (JRD; "Imagine you are standing at the cup, facing the apple. Point to the basket."). After learning from one view, JRD performance was best for imagined perspectives parallel to the learned view, reflecting an influence of the egocentric learning view on reference frame selection. After learning from two views, one of which was aligned with environmental axes defined by the rectangular room walls and a rectangular rug on the floor, performance was best for imagined perspectives parallel to the aligned study view, and performance for imagined perspectives parallel to the misaligned study view was no different than other misaligned perspectives that were never experienced. Together, these results indicate a powerful influence of environmental cues on reference frame selection, but only when experienced from a view aligned with environmental axes.

Although most research on reference frame selection has focused on the influence of egocentric and environmental cues, the presence of another person can also influence spatial representations. This is the topic of the current investigation. Successful social interaction requires that individuals consider the perspective of others (Galinsky, Ku, & Wang, 2005). Indeed, such effects have been shown with regard to spatial processing. For example, people adjust their descriptions of spatial location to accommodate a conversational partner's perspective (Mainwaring, Tversky, Ohgishi, & Schiano, 2003; Schober, 1993). When judging whether an object is left or right relative to a participant's own perspective, judgments are faster when the object is to the participant's right and when the object is near the participant. But when making similar

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✉ Jonathan W. Kelly
jonkelly@iastate.edu

[1] Department of Psychology, Iowa State University, W112 Lagomarcino Hall, 901 Stange Rd, Ames, IA 50011-1041, USA

left/right judgments relative to another person at the opposite end of a table, judgments are faster when the object is to that person's right and also when the object is closer to the other person (Cavallo, Ansuini, Capozzi, Tversky, & Becchio, 2017), demonstrating spontaneous perspective taking of another person. Making spatial judgments from one's own perspective is affected by another person's perspective (Samson, Apperly, Braithwaite, Andrews, & Bodley Scott, 2010) or even another object's perspective (Zwickel, 2009) even when that perspective is irrelevant to the task. Object judgments relative to another actor become more difficult as the angular disparity between viewer and actor increases (Michelon & Zacks, 2006), much like mental rotation (Shepard & Metzler, 1971). Despite this cognitive cost of mental transformation, the mere presence of another person in a scene can lead to spontaneous use of that person's perspective when describing object locations, especially if that person is acting upon objects in the scene (Tversky & Hard, 2009). Taken together, research indicates that the presence of another person can affect spatial processing.

The presence of another person can also affect selection of the reference frame used to represent locations in memory. In a collaborative task, one participant (the director) viewed an object layout from a single view and described it to another participant (the matcher) who recreated the layout from a different view (Galati & Avraamides, 2015; also see Galati, Michael, Mello, Greenauer, & Avraamides, 2013). Later, the director's long-term memory of the layout was assessed by drawing the layout and performing JRD. When the director was misaligned with an environmental axis and knew that the matcher would recreate the layout from an aligned view, the director remembered the layout using a reference frame aligned with the matcher's perspective. But when the director did not know the matcher's view during study, the director used a reference frame defined by egocentric experience.

To summarize, the presence of another person can cause spontaneous perspective taking (e.g., Tversky & Hard, 2009). Furthermore, a collaborative partner can affect reference frame selection (Galati & Avraamides, 2015). The current study explored whether the presence of another person affects reference frame selection in the absence of collaborative partnership. In other words, can mere presence of another person cause spontaneous selection of a reference frame aligned with that person's view? The study procedures followed those used in related research on reference frames in long-term memory (e.g., Shelton & McNamara, 2001). Learning conditions varied in the availability of cues that might influence reference frame selection during encoding of an object layout. Examples of cues in the current project include the participant's view of the to-be-learned layout and the experimenter's standing location during study. After studying, participants moved to another room and performed JRD that tested memory retrieval from various imagined perspectives, including perspectives aligned and misaligned with available cues during learning. Differences in retrieval performance across conditions are attributed to differences in the reference frame selected during learning, since no other differences existed after learning was completed.

To anticipate the results, participants in Experiment 1 selected a reference frame based on their experienced view when the experimenter simply stood next to the object layout. However, participants selected a reference frame aligned with the experimenter's perspective when required to consider that perspective during learning. Experiment 2 replicated that finding, and showed that reference frame selection was similarly influenced when participants were required to consider another perspective defined by an object rather than a person. In summary, (1) the mere presence of the experimenter did not affect reference frame selection, and (2) participants adopted a nonegocentric reference frame but did so whether the nonegocentric perspective was defined by the experimenter or an object.

Experiment 1

Participants studied a layout of objects from a single view (45° view in Fig. 1), misaligned with the axes of the surrounding room and a rug on the floor. In one condition (experimenter-absent), the experimenter stood outside the participant's view to evaluate reference frame selection without a person visible near the object layout. In two other conditions (experimenter-present with and without instruction), the experimenter stood near the participant at a view aligned with the environmental axes (0° view in Fig. 1). The two experimenter-present conditions were distinguished by whether or not the participant was instructed to consider the experimenter's view during learning by indicating whether each object was to the left, right, or center relative to the experimenter.

The specific arrangement of views (participant at 45°, experimenter at 0°) was chosen for two reasons. First, Michelon and Zacks (2006) reported that the difficulty of making left–right judgments from a nonegocentric perspective increased with angular disparity. Therefore, a smaller disparity was chosen to maximize the likelihood that participants would be able to successfully process a perspective other than their own. Second, reference frame research indicates that participants who experience multiple views of a space are inclined to select a reference frame parallel to the view aligned with environmental axes (e.g., Shelton & McNamara, 2001). Therefore, the participant was placed at a misaligned view and the experimenter at an aligned view to maximize the likelihood that participants would select a reference frame from a nonegocentric perspective.

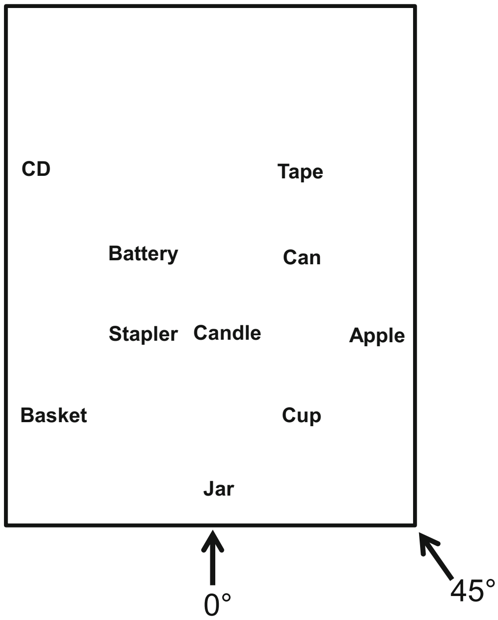

Fig. 1 Object layout used in Experiments 1 and 2. Border lines represent rug edges. Participants always viewed from 45°. Experimenter stood at 0° when visible to the participant (experimenter-present conditions)

Method

Participants Forty-nine undergraduate students at Iowa State University participated in exchange for course credit. Data from one participant were removed due to pointing errors consistent with chance performance. The remaining 48 participants were evenly distributed into the three experimental conditions. Sample size was based on past research involving between-participant manipulation of environmental cues during learning (Kelly, 2011; McNamara, Rump, & Werner, 2003; Shelton & McNamara, 2001).

Stimuli and design Learning stimuli consisted of 10 objects arranged on a 1.52-m × 2.11-m rectangular rug (see Fig. 1). The rug was located near one corner of a 5.75-m × 5.75-m room with the rug edges parallel to the room walls. Participants always viewed the layout from 45°. The experimenter stood at 0° for conditions in which he or she was visible to the participant.

Instructions and the position of the experimenter created three between-participant learning conditions. In the experimenter-absent condition, the experimenter stood outside of the participant's view during learning. In the two experimenter-present conditions, the experimenter stood at 0° while the participant studied the object layout. The experimenter-present conditions were distinguished by learning instructions. In the experimenter-present-with-instruction condition, the participant was instructed to learn the location of each object and whether it was to the left, right, or center relative to the experimenter's perspective. In the experimenter-present without instruction and the experimenter-absent conditions, the participant was simply told to learn the location of each object, and no reference was made to the experimenter's perspective.

Sixty-four JRD trials were constructed using object names. Each trial was presented as a sentence on a computer instructing the participant to imagine a specific perspective (e.g., "Imagine standing at the apple, facing the candle.") and to point to an object from that imagined perspective (e.g., "Point to the can."). Pointing was accomplished by deflecting a joystick in the intended direction. Trials tested eight imagined perspectives (0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°). Eight trials were created for each imagined perspective, and the correct pointing direction (the direction required to produce a correct response) was counterbalanced. Pointing error was the primary dependent variable, and pointing latency was also recorded.

Procedure After completing the informed consent form, the participant was blindfolded and led to the 45° view. The participant remained blindfolded while the experimenter set up the objects. The participant then lifted the blindfold and was given task instructions.

In all learning conditions, the experimenter first named the objects in a random sequence. The participant then studied for 30 seconds before replacing the blindfold and attempting to point to each object in a random order chosen by the experimenter. In addition to the pointing task during learning, participants in the experimenter-present-with-instruction condition indicated whether each object was left, right, or center relative to the experimenter's perspective (they did so after each pointing response). The experimenter immediately corrected pointing errors and left/right/center judgment errors by instructing the participant to lift the blindfold and view the correct object location. This study/test procedure was repeated three times.

After learning, the participant was blindfolded and led to another room to complete the JRD task. The blindfold was then removed and the participant was seated at a desktop computer. The experimenter provided verbal instructions regarding the JRD task, and the participant completed three practice JRD trials using locations of buildings on campus. No data were collected during JRD practice, which was included to familiarize participants with the format of the JRD task. The participant then had an opportunity to ask questions before proceeding to the JRD task involving the studied objects.

Results

Absolute pointing error was calculated as the absolute difference between the correct pointing direction and the pointing response. Pointing latency was calculated as the difference between the time when text appeared on the screen and when a pointing response was entered. Analyses focused on the effect of imagined perspective on pointing error and latency. Therefore, data from the eight repeated trials for each imagined perspective were averaged together prior to analysis. There was no evidence of speed–accuracy trade-off. The within-participant correlation between error and latency was significantly positive ($M = 0.236$, $SE = 0.054$), $t(47) = 4.38$, $p < .001$. Pointing error was more responsive to the independent variables than was pointing latency, and so the focus is on pointing error. Pointing latency data are included as Supplemental Materials.

Pointing errors (Fig. 2) were analyzed in a mixed ANOVA, with terms for imagined perspective and condition. The main effect of imagined perspective was significant, $F(7, 315) = 10.87$, $p < .001$, $\eta_p^2 = .20$, as was the interaction between perspective and condition, $F(14, 315) = 1.93$, $p = .023$, $\eta_p^2 = .08$. The interaction appeared to be driven by the distinct error pattern in the experimenter-present-with-instruction condition compared to the two other conditions. Following the significant interaction, data were further analyzed to identify the likely reference frame in these conditions.

In the experimenter-present-with-instruction condition, performance was better when imagining the 0° (experimenter-aligned) perspective ($M = 36.33°$, $SE = 3.33$) than the 45° (participant-aligned) perspective ($M = 45.32°$, $SE = 4.22$), $F(1, 15) = 7.96$, $p = .013$, $\eta_p^2 = .35$. Furthermore, there was evidence of a sawtooth pattern with facilitated performance on perspectives orthogonal to the experimenter's perspective (0°, 90, ° 180°, and 270°; $M = 40.55°$, $SE = 3.44$) compared to perspectives orthogonal to the participant's perspective (45°, 135°, 225°, and 315°; $M = 49.37°$, $SE = 3.16$), $F(1, 15) = 17.69$, $p = .001$, $\eta_p^2 = .54$.

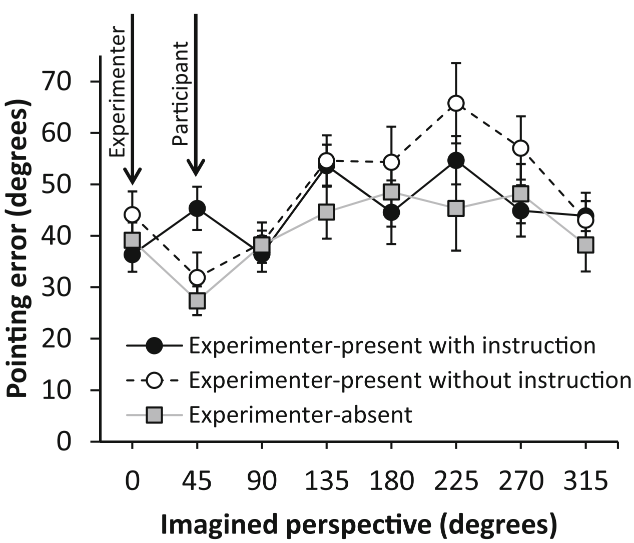

Fig. 2 Absolute pointing error in Experiment 1 as a function of imagined perspective. Error bars represent ±1 *SEM*

In the experimenter-present without instruction and the experimenter-absent conditions, performance was better when imagining the 45° (participant-aligned) perspective ($M = 29.63°$, $SE = 2.81$) than the 0° perspective ($M = 41.63°$, $SE = 2.85$), $F(1, 31) = 17.92$, $p < .001$, $\eta_p^2 = .37$. The sawtooth pattern was not significant.

Discussion

In the absence of a visible experimenter near the object layout, participants selected a reference frame parallel to the studied view even though it was misaligned with environmental axes. This finding is consistent with past work (Shelton & McNamara, 2001). The mere presence of the experimenter standing at a perspective aligned with the environmental axes was insufficient to induce spontaneous selection of an experimenter-aligned reference frame. Rather, participants in this condition selected a reference frame parallel to the studied view. However, when instructed to make object judgments relative to the experimenter's perspective during learning, participants selected a reference frame aligned with the experimenter's perspective.

These results appear to rule out the possibility that mere presence of another person could cause spontaneous selection of a reference frame aligned with that person's perspective. However, the results leave open the possibility that a nonegocentric reference frame will only be selected when considering the perspective of another person, as compared to a nonhuman object. This was the focus of Experiment 2.

Experiment 2

In the experimenter-present-with-instruction condition of Experiment 1, participants made experimenter-relative judgments of object location during learning and subsequently adopted a reference frame aligned with the experimenter's perspective. Experiment 2 explored whether similar nonegocentric reference frame selection would occur if participants learned object locations relative to the perspective of a nonhuman object. In a replication of the experimenter-present-with-instruction condition, participants were instructed to make left/right/center judgments relative to the experimenter's perspective during learning. In a second condition, the experimenter was substituted with a wooden box next to the layout and participants were instructed to make left/right/center judgments relative to the box during learning.

Method

Participants Thirty-two undergraduate students from Iowa State University participated in exchange for course credit.

Stimuli and design Stimuli were identical to those in Experiment 1 except for the 12-in. × 12-in. × 36-in. wooden box used in one condition. When present, the box was placed at 0°. A black arrow drawn on top of the box was oriented parallel with 0°.

The two between-participant conditions were experimenter-present with instruction and box-present with instruction. When the box was present, the experimenter stood outside the participant's view. In both conditions, participants were instructed to learn object locations relative to 0°, which was occupied by either the experimenter or the box. Participants subsequently made left/right/center judgments about objects while pointing to them during learning. JRD trials were identical to those used in Experiment 1.

Results

There was no evidence of speed–accuracy trade-off. The within-participant correlation between error and latency was significantly positive ($M = 0.210$, $SE = 0.071$), $t(31) = 2.94$, $p = .006$. Pointing error was more responsive to the independent variables than was pointing latency, and so the focus is on pointing error. Pointing latency data are included in the Supplemental Materials.

Pointing errors (see Fig. 3) were analyzed in a mixed ANOVA, with terms for imagined perspective and condition. The main effect of imagined perspective was significant, $F(7, 210) = 13.531$, $p < .001$, $\eta_p^2 = .31$. Neither the main effect of condition nor the interaction were significant. Performance was better when imagining the 0° (experimenter-aligned or box-aligned) perspective ($M = 35.11°$, $SE = 2.91$) than the 45° (participant-aligned) perspective ($M = 49.23°$, $SE = 3.58$), $F(1, 31) = 9.46$, $p = .004$, $\eta_p^2 = .23$. Furthermore, there was evidence of a sawtooth pattern with facilitated performance on perspectives orthogonal to the perspective of the experimenter or box (0°, 90°, 180°, and 270°; $M = 44.42°$, $SE = 2.64$) compared to perspectives orthogonal to the participant's perspective (45°, 135°, 225°, and 315°; $M = 55.87°$, $SE = 2.71$), $F(1, 31) = 20.00$, $p < .001$, $\eta_p^2 = .39$.

Discussion

When instructed to make object judgments relative to another perspective during learning, participants selected a reference frame aligned with that perspective whether it was occupied by the experimenter or by a box with an arrow on top. The experimenter-present data are consistent with those in Experiment 1. The finding that a wooden box with an arrow on top produced the same error pattern indicates that selection of a nonegocentric perspective does not require another person, and that a nonhuman object occupying the instructed perspective had the same effect as an experimenter occupying that perspective.

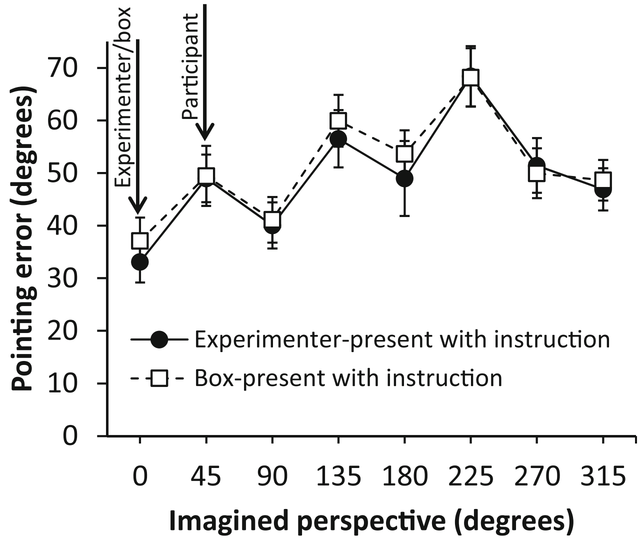

Fig. 3 Absolute pointing error in Experiment 2 as a function of imagined perspective. Error bars represent ±1 *SEM*

General discussion

In two experiments, participants who were instructed to process object locations from a nonegocentric perspective represented those objects in memory using a reference frame parallel to the instructed perspective, and reference frame selection was unaffected by whether the instructed perspective was occupied by a social or nonsocial entity. Participants given no instructions about processing from a particular perspective selected a reference frame parallel to the studied view, and mere presence of a human experimenter at a different perspective had no impact on reference frame selection. Taken together, these results indicate that presence of another person during learning did not affect the reference frame organization of spatial memory.

Previous research indicates that spatial learning and spatial language are impacted by the presence of another person (Cavallo et al., 2017; Galati & Avraamides, 2015; Galati et al., 2013; Mainwaring et al., 2003; Schober, 1993). However, that work has typically involved tasks in which the other person is relevant to task performance (e.g., a collaborative partner). In one study (Tversky & Hard, 2009) in which the other person was not an integral part of the task, participants were asked to judge the spatial locations of objects in a scene that included another person. When that person was reaching for an object in the scene, approximately 30% of participants referenced the person when describing the object's location. That number increased to more than 50% when the question referenced the actor's action. Several differences between the study by Tversky and Hard and the current experiments could be responsible for the different outcomes. For example, the dependent measure used by Tversky and Hard was a verbal description, compared to memory-based perspective-taking performance in the current study. Furthermore, the actor used by Tversky and Hard was in full view in the center of the photograph, whereas the experimenter in the current study was to the side of the layout from the participant's view. Lastly, participants in Tversky and Hard were most likely to adopt the actor's reference frame when he was reaching for one of the objects in the scene, and the experimenter in the current experiments simply stood next to the layout without acting on the objects.

Research on reference frame selection generally indicates that a reference frame is selected from a studied view (Shelton & McNamara, 2001). When multiple studied views are experienced, the reference frame is typically selected from the view aligned with salient environmental axes, such as room walls or axes (Shelton & McNamara, 2001; Kelly & McNamara, 2008; Kelly, Sjolund, & Sturz, 2013). There are few examples in spatial memory research in which participants select a reference frame parallel to a view not directly experienced during learning. One exception is a study reported by Mou and McNamara (2002; also see Street & Wang, 2014) in which participants were instructed to learn object locations in columns organized parallel to a nonegocentric perspective. The current experiments differed in that participants were never instructed to learn the objects relative to another perspective, but in some conditions they were required to process information from a nonegocentric perspective by judging whether an object was left, right, or center relative to that perspective. Such processing relative to a nonegocentric perspective was sufficient to induce reference frame selection, and indicates that reference frame selection may be more flexible than previously thought.

The present studies found that reference frame selection was influenced by the instructed perspective for both social and nonsocial entities. These findings, combined with previous work reviewed above, suggest that the social effects of spatial perspective taking are restricted to situations in which the social entity is relevant to the present task. It is possible that the effect of another person on reference frame selection could be moderated by the social relationship between the participant and the other person. For example, research indicates that perspective taking varies as a function of interpersonal similarity (Todd, Hanko, Galinsky, & Mussweiler, 2011), interpersonal emotions (Bukowski & Samson, 2016), and relative power between the perceiver and the target individual (Galinsky, Magee, Inesi, & Gruenfeld, 2006). Accordingly, reference frame selection might similarly vary to the degree there exists a relationship between the perceiver and target individual.

To summarize, these results indicate that an experimenter standing within a scene does not affect reference frame selection. The mere presence of an experimenter did not affect reference frame selection, and participants were capable of adopting a nonegocentric reference frame whether the nonegocentric perspective was occupied by the experimenter or an object.

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