The intrinsic structure of spatial configurations and the partner's viewpoint shape spatial memories and descriptions

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Abstract

We examined how the intrinsic orientation of spatial layouts and the conversational partner's viewpoint shape how people organize spatial information in memory and subsequently describe it. In 24 pairs, Directors first studied an array with a symmetrical structure while either knowing their Matcher's subsequent viewpoint or not. When describing the array to the Matcher, the array's intrinsic orientation was aligned with the Director, the Matcher, or neither partner. Memory tests preceding descriptions revealed that Directors misaligned with the structure organized information according to a priori knowledge, being more likely to use the structure as an organizing orientation when knowing that Matchers were aligned with it. The perspective of Directors' descriptions was also influenced both by the partners' alignment with the structure and their advance knowledge of that. Altogether, speakers are guided by converging social and representational cues to adapt flexibly the organization of their memories and perspectives of their descriptions.

Keywords: perspective-taking; spatial memory; intrinsic structure; audience design; common ground; spatial descriptions

Introduction

When people make spatial judgments they access memory representations that maintain spatial relations around a preferred direction (e.g., Mou, McNamara, Valiquette, & Rump, 2004). This preferred direction can be influenced by egocentric preferences for organizing information, based on one's learning perspective (Shelton & McNamara, 2001) and on representational cues like the symmetry of the spatial configuration (Mou & McNamara, 2002; Li et al, 2011) or the geometry of the environment (Shelton & McNamara, 2001). However, the extent to which people take into account their conversational partner's viewpoint when organizing information in memory and communicating this information is still unclear.

A study by Shelton and McNamara (2004) addressed whether describing information from the partner's viewpoint influences speakers' resulting memory representations. Indeed, after describing an array to their partner, speakers were more accurate to make spatial judgments from perspectives aligned with the one that had been occupied by their partner (vs. other perspectives). However, since speakers learned the arrays while describing them from the partner's viewpoint (following explicit instructions), it's possible that speakers don't spontaneously represent their partner's viewpoint in spatial memory, and instead resort to egocentric preferences for organizing information.

We recently adapted Shelton and McNamara's (2004) study to ask whether in fact speakers spontaneously represent their partner's viewpoint in memory. In Galati et al. (2013), one participant (the Director) first studied a randomly configured array, while either knowing or not knowing their partner's (the Matcher's) subsequent viewpoint, which was misaligned by 90°, 135°, or 180°. In memory tests preceding descriptions, rather than finding facilitation for the partner's viewpoint when it was available (cf. Shelton & McNamara, 2004), we found that speakers represented that viewpoint in memory without using it as an organizing direction. Directors took longer to imagine orienting to perspectives known to be aligned with their Matcher (at least for 90° and 135°) and rotated their array drawings toward the Matcher's viewpoint. Nonetheless, these findings could indicate that, under those circumstances, speakers did not have sufficient pragmatic motivation to invest the cognitive effort to organize spatial relations around a non-egocentric viewpoint, so they simply represented it and used it as needed.

In the present study, our first goal is to elucidate whether, under different circumstances, the partner's viewpoint *could* be used as an organizing direction in memory. In particular, we ask whether, in collaborative tasks, a given partner's alignment with the array's intrinsic structure affords sufficient pragmatic motivation to organize spatial relations around that viewpoint. Our view is that, when selecting an organizing direction, people consider a confluence of different sources of information, including egocentric cues (e.g., their own learning viewpoint), representational cues (e.g., the array's intrinsic orientation) and social cues (e.g., the partner's viewpoint). Thus, the partner's viewpoint could be used as an organizing direction if it is reinforced by additional cues, like the array's intrinsic orientation. This prediction follows the proposal that in collaboration people try to minimize their collective effort, with one partner investing greater cognitive effort to ensure mutual understanding upon appraising that the other is likely to find the interaction difficult (e.g., Clark & Wilkes-Gibbs, 1986). In spatial perspective-taking, attributions about the partner's ability to contribute to the task, based on social cues, should influence whether the partner's perspective is adopted.

This is in line with findings concerning the interpretation of spatial descriptions. For instance, when people believe that their partner doesn't know their viewpoint they are more likely to interpret spatial descriptions from the partner's perspective, whereas when they believe that their partner is real (vs. simulated) they are more likely to interpret them egocentrically presumably because they shift the burden of ensuring mutual understanding to the partner (Duran, Dale, & Kreuz, 2011). Related findings come from production tasks as well. People invest the cognitive effort to describe information from their partner's perspective when the partner does not share their viewpoint (Schober, 1993),cannot provide feedback (Shelton & McNamara, 2004), or has worse spatial abilities than them (Schober, 2009). People are also more likely to help their partners by using available environmental features, like the intrinsic axes of objects, as the basis of their descriptions' perspective, instead of their own egocentric perspective (Tenbrink, Coventry, Andonova, & 2011), and referring to more landmarks for orienting, and navigating along fewer, larger and more prominent streets when describing routes to a partner unfamiliar with the environment (Hölscher, Tenbrink, & Wiener, 2011).

Thus, the second goal of our study is to examine how people adapt their spatial descriptions when faced with different cues. Specifically, we aim to clarify the extent to which they rely on their memory representations when describing information. We do so by dissociating the learning of spatial arrays from their description (cf., Shelton & McNamara, 2004). Our earlier work suggests that speakers don't merely rely on their initial representations during descriptions, but are able to use available perceptual information (i.e., their degree of misalignment from their partners) to adapt descriptions appropriately (Galati et al., 2013). Here, we examine whether advance knowledge of the partner's viewpoint guides speakers in selecting a perspective for their descriptions, depending on whether the intrinsic structure is aligned with the speaker, their partner, or neither partner during the description. If the convergence of available cues during the description strongly biases a particular perspective, then advance knowledge of the partner's viewpoint may not influence descriptions significantly. On the other hand, advance knowledge of the partner's viewpoint and its relation to the intrinsic structure may highlight alternative perspectives for both encoding and describing the array.

Method

Design

Directors first studied an array with an intrinsic structure, then had their memory of the array tested, and finally described the array to a partner, their Matcher, who reconstructed the array on the basis of the Directors' descriptions. We manipulated the alignment of the array's intrinsic structure with either partner during the description phase, as well as the partners' advance knowledge of that. In a third of the pairs, Directors studied arrays while aligned with its intrinsic structure (referred to as 0°, see Figure 1), and later described it to Matchers who were offset by 135° measured counterclockwise (*Aligned with Director* condition). In another third of the pairs, Directors studied arrays from 225° and later described it to Matchers who were at 0° (*Aligned with Matcher* condition). In the final third of the pairs, Directors studied arrays again from 225° and later described to Matchers who were offset by 135°; thus both partners were misaligned with the structure (*Aligned with Neither* condition). Half of the Directors in each condition studied the array while knowing where their Matcher would later be, whereas the remaining half didn't.

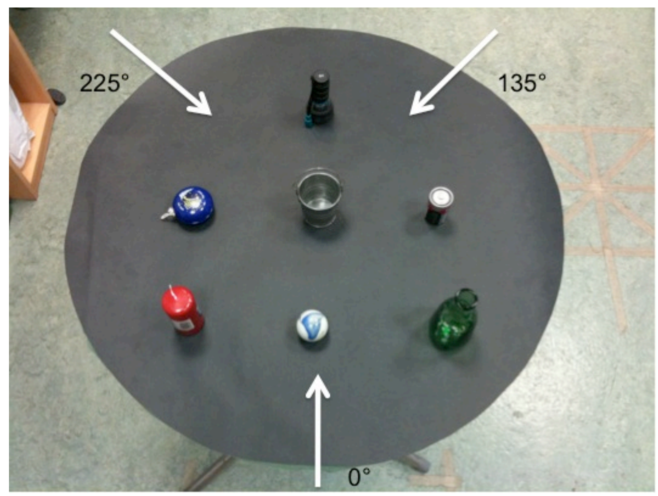


Figure 1: The seven-object array used, indicating 0º, 135º, and 225º headings.

Participants

Forty-eight undergraduate and graduate students from the University of Cyprus participated, half of them as Directors and half as Matchers, in 24 pairs. Six were female-female pairs, 6 were male-male pairs, 6 were mixed-gender pairs with female Directors, and 6 were mixed-gendered pairs with male Directors. All pairs of participants were recruited to be friends.

Procedure

Study phase After a practice phase during which Directors were familiarized with the *Judgments of Relative Direction* (JRD) task (see below), Directors studied an array with an intrinsic axis of symmetry, comprising seven common objects that lacked intrinsic front-back and left-right axes, displayed on a 70 cm-diameter circular table (Figure 1).

Directors studied the array while either aligned or misaligned with its structure (from either 0° or 225°), while either knowing where their Matcher would be during the description phase or not. When the Matcher's viewpoint was known, Matchers sat at a separate, identical table next to the Director's (see Figure 2), at the position they would occupy during the description (at 0° or at 135°).

Testing phase After ensuring that Directors memorized the array, Directors moved to an adjacent room to complete the memory tasks (JRDs and the drawing task). On JRD trials, Directors were instructed to imagine being at one location facing a second, constituting an imagined heading or viewpoint, and to point to a third object, the target (e.g., *Imagine being at the bucket, facing the marble. Point to the candle*.). Directors first read a statement in this form (i.e., "*Imagine being at x, facing y*"), pressed a button on a joystick once they adopted that heading, and then responded to the second statement ("*Point to z*") by deflecting the joystick in the direction of z as if they were facing y and pressing a button to log in their response. Sixty-four such trials were presented individually on a computer screen. They included eight imagined headings (0°, 45°, 90°, 135°, 180°, 225°, 270°, 315° relative to the intrinsic structure) and their order was randomized.

After the JRDs, Directors did an array drawing task. They were given 20 cm-diameter grid (with 1 mm lines) and were asked to reconstruct as accurately as possible the studied array by placing seven circular transparent markers, each labeled with a name of the array's objects, on the grid.

Description phase After their testing phase, Directors returned to the original room for the description. Pairs sat at the positions prescribed by their condition of alignment with the array's intrinsic structure. Directors described the array's configuration from memory, while the Matcher used the seven objects to reconstruct the array at their table. Instructions emphasized that participants could interact freely and that they should reconstruct the array so that, given the Director's study viewpoint, objects be translated to the Matcher's table (i.e., not rotated by the Matcher's offset). Although pairs could interact freely, Directors could not look over the barrier (113 cm tall) separating the two tables; they could see each other's faces but not each other's tabletops. After turning on the cameras, the experimenter left the room for the description phase. After completing the description phase, pairs were debriefed and compensated for their time, if participating for payment.

Coding of Spatial Descriptions

Each pair's interaction during the description phase was transcribed in detail, including contributions by both Directors and Matchers. We adapted our coding scheme from Galati et al. (2013) to classify spatial expressions in the Directors' turns as:

a. Director-centered, e.g., "in front of me is the marble"
b. Matcher-centered, e.g., "the vase is to your left"
c. Structure-centered, e.g., "it's on the perpendicular line. You're supposed to be on one side on the left, and I'm on one right side of the table"

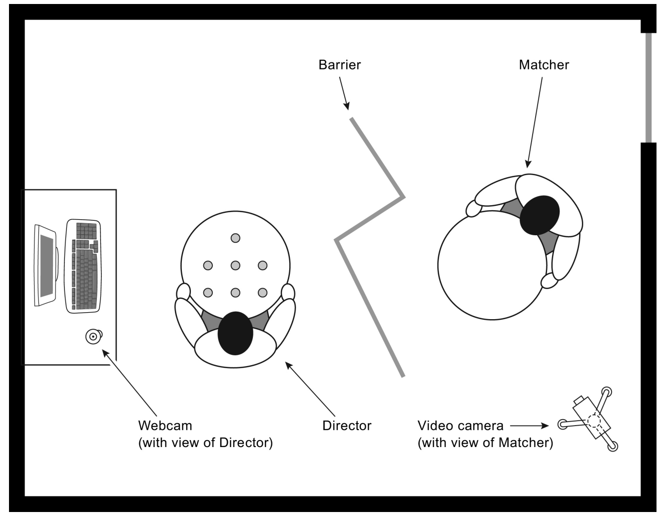


Figure 2: Set-up of a study phase in which the Director was aligned with the array's intrinsic structure (at 0°), while the Matcher was misaligned with it (at 135°).

d. Neutral, capturing inter-object relations independently of a particular viewpoint, e.g., "it's close to the bucket" or "they form a triangle"
e. Other headings, not coinciding with the Director's, the Matcher's, or the structure's intrinsic orientation, e.g., "say the candle is facing the bucket; from the bucket, it's on the left"
f. Ambiguous, when expressions could be interpreted as involving more than one of coding categories

Three more categories (both-centered, environment-centered, and object-centered) will not be considered further since they constituted less than 1.5% of all 1609 spatial expressions.

Reliability The first author coded 20 pairs, while a second coder redundantly coded 6 pairs as well as the remaining 4 pairs. Prior to comparing their judgments, the coders discussed 52 instances for which there was disagreement over the segmentation of spatial expressions (i.e., cases where one coder identified a spatial expression while the other didn't, or parsed a phrase as two spatial expressions while the other did as one). These disagreements were resolved by discussing them until consensus was reached; the remaining, non-redundantly coded dialogues were checked for consistent application of the agreed upon criteria. For the 383 spatial expressions from the redundantly coded dialogues, the two coders made identical classifications 98% of the time, Kappa= .98, $p < .001$.

Results

Spatial Memory

Array drawings When Directors studied the array while aligned with the intrinsic structure (from 0°), all of them used the structure as the organizing direction of their drawings, whether they knew the Matcher's viewpoint (135°) or not. On the other hand, as Table 1 shows, when they studied the array while misaligned with its structure (from 225°), the orientation of their drawings depended on whether they knew their Matcher's viewpoint. When the Matcher's viewpoint was unavailable, they were more likely to use their learning viewpoint (225°) to draw the array. But when they had known in advance that the Matcher was aligned with the array's structure, they used the structure's axis as an organizing direction more frequently. And when they had known in advance that the Matcher would also be misaligned with the structure (at 135°), half of the Directors opted for their learning viewpoint, while half used the axis of the structure as their organizing direction. The probability that the overall distribution of the drawings' orientation was observed by chance is small (*p*= .03, Fisher's exact test).

Table 1: Proportion of Directors who drew arrays as aligned with the intrinsic structure vs. from own viewpoint, when having studied arrays from 225°.

	Aligned with intrinsic structure	Aligned with learning viewpoint
Knows Matcher is at 0°	.75	.25
Knows Matcher at 135°	.50	.50
Does not know Matcher's viewpoint	.25	.75

Judgments of Relative Direction Analyses of JRD performance were initially conducted while ignoring the organization suggested by the Directors' drawings. However, these results were obfuscated by the fact that, as Table 1 illustrates, when misaligned with the structure, Directors were split in their preferred orientation at any given condition of availability of the Matcher's viewpoint. For instance, although most Directors preferred the structure's axes when knowing that the Matcher would be aligned with the structure, some still preferred their learning orientation. Thus, subsequent analyses of JRD performance centered on corroborating that Directors organized object relations in memory as indicated by their drawings' orientation.

As Figure 3 illustrates, the Directors' orientation latency (time to orient to an imagined heading) was consistent with the preferred orientation of their array drawings. Directors whose drawings were aligned with the structure were generally faster to orient to the structure's canonical axes (0°, 90°, 180°, 270°) than to the oblique headings (45°, 135°, 225°, 315°). This pattern was reversed when Directors had drawn arrays from 225°. Indeed, the interaction between the heading from which the array was drawn and the JRD trial's imagined heading was significant, $F(7, 154) = 4.96$, $p < .001$.

We examined this sawtooth pattern of performance by fitting planned contrasts with weights: - 1.625, .875, -0.625, 1.375, -1.625, 1.375, -0.625, .875. This contrast, with the minimums at 0º and 180º, adequately described the orientation latencies of Directors who drew arrays aligned with the structure, $F(1, 14) = 10.34$, $p < .01$, accounting for 88% of the variance associated with the imagined heading and leaving a non-significant amount of variance unaccounted for ($p = .98$). For Directors who drew arrays from their 225º study viewpoint, the sawtooth contrast with the minimums at 225° and its counteralinged heading (45°) also described performance adequately, $F(1, 8) = 6.43$, $p < .05$, accounting for 62% of the variance associated with the imagined heading and leaving a non-significant amount of variance unaccounted for ($p = .82$).

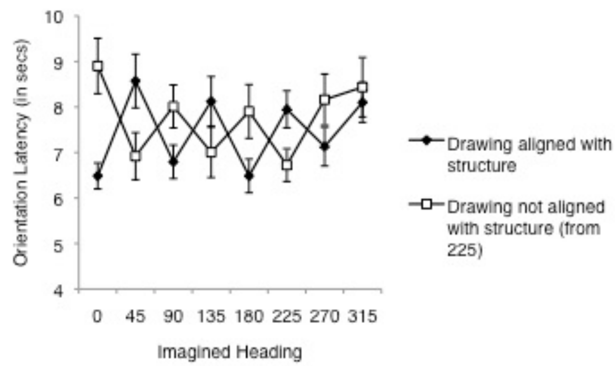


Figure 3: Orientation latencies (in secs) across imagined headings according to how Directors had drawn arrays

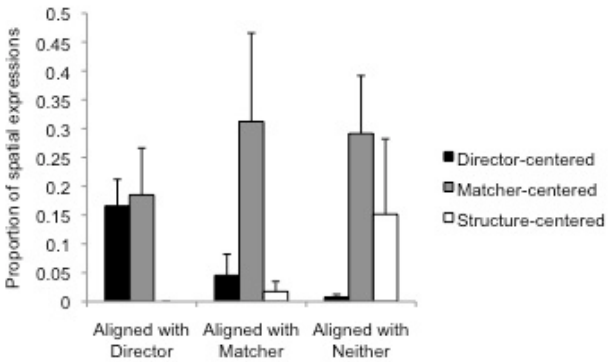
The same pattern was observed for Directors' response latency (the time to point to the target after adopting an imagined heading) and their pointing error (the unsigned angular deviation of the joystick response from the veridical response). For brevity, these analyses are not reported here.

Spatial Descriptions

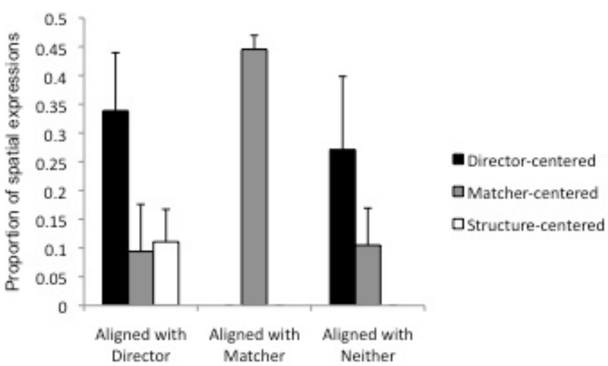
Overall, Directors produced most frequently Neutral expressions in their descriptions (48% of all spatial expressions), with Matcher-centered expressions constituting 20%, Director-centered 15%, Structure-centered 8%, other headings 2%, and ambiguous expressions 5% of all expressions.

We will focus on the distribution of Director-centered, Matcher-centered, and Structure-centered expressions, given our manipulation of the alignment of the intrinsic structure with either partner. The distribution of these three types of spatial expressions indeed depended on the partners' alignment of the intrinsic structure during the description, $F(4, 36) = 3.96$, $p < .01$. This interaction was driven by Directors using more Matcher-centered expressions than Director-centered ones when the Matchers were aligned with the structure (95% CI[-.56, -.15], $p < .01$), whereas the reverse was true when Directors were the ones aligned with the structure (though this difference was not statistically significant: 95% CI[-.09, .32], $p = .27$).

On its own, the availability of the Matcher's viewpoint didn't reliably affect the distribution of these spatial expressions; this interaction was not significant, $F(2, 36)= 1.83$, $p= .18$. Nonetheless, Directors used significantly more Matcher-centered expressions than Director-centered ones (26% vs. 7%) when they knew the Matcher's viewpoint in advance (95% CI[-.36, - .02], $p < .05$), whereas they used comparable proportions (21% vs. 20%) when they hadn't known their Matcher's viewpoint (95% CI[-.18, .15], *n.s.*).



(a)



(b)

Figure 4: Proportion of Director-centered, Matcher-centered, and Structure-centered expressions when the Matcher's viewpoint was available (a) or unavailable (b) at study, across the partners' alignment with the intrinsic structure.

As Figure 4a shows, Directors who studied arrays from 0° while knowing that their Matcher would be offset by 135° used comparable proportions of egocentric and Matcher-centered expressions in their descriptions (17% vs. 18%; 95% CI[-.31, .27], *n.s.*). On the other hand, as Figure 4b shows, they tended to use more egocentric expressions (34% vs. 10%) when their Matcher's viewpoint wasn't available at study (95% CI[-.05, .54], $p= .10$). When the Matcher was at 0° during the description, Directors used predominately Matcher-centered expressions whether this information was available in advance or not. Finally, when neither partner was aligned with the structure during the description, the distribution of expressions differed depending on whether Directors knew this in advance. As Figure 4b shows, when Directors hadn't known the Matcher's viewpoint in advance, they used numerically more egocentric than Matcher-centered expressions (27% vs. 10%; 95% CI: [-.13, .46], $p= .25$), whereas as Figure 4a shows, when they had known it in advance, they used more Matcher-centered than egocentric expressions (29% vs. 1%; 95% CI: [-.58, .01], $p= .06$). Moreover, as suggested by the white bars across the two figures, Directors used numerically more Structure-based descriptions when they knew in advance that Matchers would also be misaligned with the structure than when they didn't (95% CI: [-.33, .02], $p= .08$).

The distribution of spatial expressions that Directors used was not influenced by the pair's gender combination or the gender of the Director; the interaction of each of these factors with the type of spatial expression was not significant: $F(6, 40)= .87$, $p= .52$, for the pair's gender combination, and $F(6, 40)= .85$, p= .44 for the Director's gender.

Discussion

Our findings suggest that people consider both representational and communicative factors when organizing spatial information in memory and when selecting the perspective from which to describe that information. The preferred direction around which people organize spatial relations in memory depends on whose viewpoint is reinforced by the configuration's intrinsic orientation. This was demonstrated by the Directors' drawings and was corroborated by their performance in the JRD task. When Directors were aligned with the intrinsic structure, they defaulted to their own viewpoint as the organizing direction, regardless of what they knew about their partner's viewpoint. On the other hand, when they were misaligned with the structure during learning, knowing that their Matchers would be aligned with the structure's orientation increased the probability of using the structure's axes as an organizing direction. Moreover, knowing that the Matcher would also be misaligned with the structure increased the probability of using the structure's axes as an organizing direction compared to not knowing the Matcher's viewpoint.

These findings suggest that a given partner's alignment with the intrinsic structure affords sufficient pragmatic motivation to organize spatial relations from that orientation: when the structure's orientation is aligned with a partner's viewpoint, these converging cues influence the preferred orientation that people use. This extends our earlier findings that, when no intrinsic structure is available, people encode the partner's viewpoint in memory but don't necessarily use it as an organizing direction, likely due to insufficient pragmatic motivation to do so when they can freely interact with their partner (Galati et al, 2013).

We propose that, when selecting the preferred orientation of their spatial memories, people combine probabilistically different sources of information. When the intrinsic structure and their own learning viewpoint converge, they use that egocentric viewpoint; when the intrinsic structure and their partner's viewpoint converge, they opt for the partner's viewpoint. This also held for how speakers adapted their spatial descriptions. When the intrinsic structure and the Director's learning viewpoint converged, Directors tended to describe spatial information from their own perspective, with Matchers having to unpack the spatial mappings of these Director-centered descriptions. When the intrinsic structure and Matcher's viewpoint converged, Directors alleviated the Matcher's cognitive burden by describing spatial information from the Matcher's viewpoint. Speakers used the available social and representational cues to adapt their descriptions in ways that minimized their collective effort (e.g., Clark & Wilkes-Gibbs, 1986), with the assumption here being that a perspective supported by converging cues is optimally effective.

Moreover, speakers flexibly used information that was perceptually available in the communicative setting and didn't merely rely on the organization of the memories. For instance, when Directors who studied the array from 225° without knowing their Matchers viewpoint later interacted with a Matcher at 0°, they used overwhelmingly Matcher-centered descriptions, even though most of them had used their own viewpoint as an organizing direction in memory. This is consistent with findings that, in describing spatial information, people do not always adhere to their memory's organizing direction when it conflicts with perceptual evidence (Li et al, 2011). Altogether, the adaptation we report here underscores that people use all relevant information as soon as it becomes available (whether at study or at collaboration) to make attributions about their respective ability to contribute to the task. This is in line with the view that probabilistic constraints on information processing influence perspective-taking behavior in conversation (e.g., Hanna, Tanenhaus, & Trueswell, 2003).

Our study offers a caveat on earlier demonstrations that the misalignment between partners influences perspective-taking (e.g., Duran, Dale, & Kreuz, 2011; Schober, 1993), by highlighting that misalignment interacts with other representational cues. When Directors were at 0° and Matchers at 135°, Directors overall opted for their own perspective in descriptions, presumably because reasoning from an oblique perspective was computationally more difficult (especially when not made salient at study). However, when Matchers were at 0° and Directors at 225° (also a 135° offset), Directors readily adopted their partner's perspective in descriptions. Thus, misalignment on its own does not determine the preferred perspective of speakers' descriptions.

In sum, in collaborative spatial tasks people adapt their memory representations and linguistic behavior in nuanced ways. They consider converging communicative and representational cues, whenever they become available, to appraise whose perspective would be optimal for efficient coordination; this influences whether they encode their partner's available viewpoint in memory and adopt it in descriptions.

Acknowledgments

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