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The conversational partner's perspective affects spatial memory and descriptions

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ABSTRACT

We examined whether people spontaneously represent the partner's viewpoint in spatial memory when it is available in advance and whether they adapt their spontaneous descriptions accordingly. In 18 pairs, Directors studied arrays of objects while: (1) not knowing about having to describe the array to a Matcher, (2) knowing about the subsequent description, and (3) knowing the Matcher's subsequent viewpoint, which was offset by 90°, 135°, or 180°. In memory tests preceding descriptions, Directors represented the Matcher's viewpoint when it was known during study, taking longer to imagine orienting to perspectives aligned with it and rotating their drawings of arrays toward it. Conversely, when Directors didn't know their Matcher's viewpoint, they encoded arrays egocentrically, being faster to imagine orienting to and to respond from perspectives aligned with their own. Directors adapted their descriptions flexibly, using partner-centered spatial expressions more frequently when misaligned by 90° and egocentric ones when misaligned by 135°. Knowing their misalignment in advance helped partners recognize when descriptions would be most difficult for Directors (at 135°) and to mutually agree on using their perspective. Thus, in collaborative tasks, people don't rely exclusively on their spatial memory but also use other pertinent perceptual information (e.g., their misalignment from their partner) to assess the computational demands on each partner and select strategies that maximize the efficiency of communication.

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Introduction

When people provide driving directions, describe places they have been to, or instruct a colleague about where to locate a folder in the office, they rely on their ability to recall accurately and communicate effectively spatial information. In such situations, where people try to achieve mutual understanding or a joint goal, they routinely consider their conversational partner's specific needs, knowledge, or perspective and adjust their behavior accordingly (Clark, 1996; Clark & Carlson, 1982; Clark & Murphy, 1982). For example, they may consider how familiar their partner is with the environment and adjust the detail of their descriptions (Hölscher, Tenbrink, & Wiener, 2011; Isaacs & Clark, 1987). Or, if they occupy a different vantage point than their partner, as they often do when providing directions over the phone or when moving a piece of furniture together, they may tailor their spatial descriptions to their partner's perspective (e.g., Schober, 1993, 1995).

Making a spatial judgment, and presumably also communicating spatial information, involves accessing memory representations that maintain the spatial relations between objects and are organized around a preferred

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direction (e.g., McNamara, 2003; Mou, McNamara, Valiquette, & Rump, 2004). The preferred direction of these representations is determined by various sources of information, including their initially experienced perspective (Shelton & McNamara, 2001), the environment's geometry (Shelton & McNamara, 2001), the symmetry or intrinsic structure of the spatial configuration (Li, Carlson, Mou, Williams, & Miller, 2011; Mou & McNamara, 2002), the functional features of landmarks in the configuration (Taylor & Tversky, 1992), as well as instructions emphasizing a particular orientation (Greenauer & Waller, 2008). In other words, the preferred organizing direction that people adopt is not limited to egocentric experience, but can be aligned with non-experienced perspectives reinforced by other cues.

In this work, we examine whether the partner's viewing perspective also serves as such a cue (when available), contributing to how people spontaneously organize spatial information in memory and how they subsequently describe this information. We begin by surveying studies using collaborative tasks that highlight some of the cognitive and social factors that influence spatial perspective-taking. These studies underscore that, on the basis of a number of cognitive and social constraints, people make attributions about the partner's ability to contribute to the task at hand, which influence whether they adopt their partner's perspective. Because these studies typically focus only on people's linguistic choices, it remains unclear (a) whether the partner's perspective is encoded in the memory representations supporting perspective-taking in communication, and (b) the extent to which, when communicating spatial information, people rely on the organization of these memory representations that potentially encode their partner's perspective. With this motivation, we then present our study and, using theoretical frameworks from conversational perspective-taking, make predictions about the circumstances under which the partner's viewpoint is represented in spatial memory and affects spatial descriptions.

Cognitive and social constraints on spatial perspective-taking

There has been some debate about the extent to which people readily adopt their partner's perspective in conversation. When people share the same linguistic or physical perspective, adopting the partner's perspective may be trivially easy. Under these circumstances of having same viewpoint (whether spatial or conceptual), linguistic or behavioral adjustments may be generic and not specific to the partner's needs (Brown & Dell, 1987; Dell & Brown, 1991). When people have perspectives or knowledge distinct from their partner's, some studies suggest that speakers initially behave egocentrically, failing to take the partner's perspective into account and considering it only later in order to repair misunderstandings (Horton & Keysar, 1996; Keysar, Barr, Balin, & Paek, 1998; Keysar, Barr, & Horton, 1998; Pickering & Garrod, 2004). However, other studies demonstrate that under the right circumstances people can adapt early and flexibly to their partner's perspective (e.g., Hanna, Tanenhaus, & Trueswell, 2003; Metzing & Brennan, 2003). According to this latter view, failures in perspective-taking occur when executive functioning is taxed (Brown-Schmidt, 2009) or when information about the partner isn't available early enough (Kraljic & Brennan, 2005) or requires complex inferences (Gerrig, Brennan, & Ohaeri, 2000). But when information about the partner can be represented as simple, relevant distinctions, it can have an immediate effect on behavior, particularly if these distinctions are computed easily and known early (e.g., Brennan & Hanna, 2009; Galati & Brennan, 2010).

Our hypothesis is that the factors predicting adaptation during non-spatial perspective-taking predict adaptation in spatial perspective-taking as well. Thus, speakers' cognitive constraints should influence not only whether they readily consider their partner's conceptual perspective, knowledge, or agenda (see Schober, 1998) but also whether they consider their partner's spatial viewpoint. More specifically, both the speaker's own and their partner's cognitive constraints in adopting the other's perspective should influence whose perspective is selected in conversation. Indeed, the relative cognitive demands of partners, depending on their misalignment, influence speakers' descriptions: compared to when partners share the same perspective, speakers with misaligned partners are more likely to adopt their partner's perspective and use partner-centered descriptions (e.g., "to your left" or "in front of you") than egocentric ones (Schober, 1993, 1995). The partners' relative cognitive demands, depending on the framing of the task, also influence spatial descriptions (Mainwaring, Tversky, Ohgishi, & Schiano, 2003). Replicating Schober (1993, 1995) and Mainwaring and colleagues (2003) found that when speakers described spatial information to a misaligned imaginary partner, who presumably bore more of the cognitive burden, they were more likely to adopt their partner's perspective than their own. Conversely, when speakers described spatial information for themselves, thus bearing the cognitive burden exclusively, they were more likely to adopt their own perspective than their partner's. And when the cognitive burden was presumably more equally distributed, when speakers formulated yes/no questions to request spatial information, they were more likely to use neutral perspectives (including landmarks and compass directions) than person-centered ones.

These findings are consistent with the proposal that partners follow *the principle of least collaborative effort*: they share responsibility for mutual understanding and adapt their behavior to maximize the efficiency of communication, while minimizing the collective effort of themselves and their partner (Clark, 1996; Clark & Wilkes-Gibbs, 1986). Such adaptation is especially evident when the partners' respective ability to contribute to the task differs, as when there are asymmetries in visual evidence about the partner's progress in a task (Brennan, 2004), or when interacting with a non-native speaker (Bortfeld & Brennan, 1997). Evidence for such adaptation in spatial perspective-taking comes from a task where partners were preselected to have matched or mismatched spatial abilities, assessed by a mental rotation task

(Schober, 2009). Consistent with their individual cognitive constraints, high-ability speakers were more likely to use partner-centered descriptions when describing a configuration, whereas low-ability speakers were more likely to use egocentric ones. Critically, over time, high-ability speakers describing configurations to low-ability partners increased their use of partner-centered descriptions, whereas low-ability speakers describing to high-ability partners decreased their use of partner-centered descriptions. This underscores that speakers adapt their descriptions according to the attributions they make about each other's relative knowledge or ability to contribute to the task, with the partner with the greater knowledge or ability expending greater effort to ensure mutual understanding.

Similarly, social cues about the partner's ability to contribute to the task modulate whether people invest in adopting their partner's perspective, even when doing so is more cognitively difficult. Recently, Duran and colleagues (2011) examined spatial perspective-taking in a task in which participants responded to requests for an object from a simulated partner (e.g., "give me the folder on the left"). Both partners were depicted as sitting around a round tabletop on which there were two folders, such that on some trials the partner's request was ambiguous (e.g., the request for "the folder on the left" was ambiguous when the participant was depicted to be at 0° and the partner at 270° with folders at the top-right and the bottom-left of the table from the participant's perspective). Based on their mouse-tracked responses on such trials, participants were classified as either responding egocentrically or from their partner's perspective. Across experiments, participants' preference for the partner's perspective was modulated by attributional cues. Being told that their partner did not know where they were seated (and therefore could not consider their perspective) increased partner-centered responding, despite its associated cognitive cost relative to egocentric responding, reflected in longer response times, greater deviations of the cursor towards the competitor folder, more frequent switches in the cursor's direction, and more "acceleration components" (e.g., slowing down and then speeding up, reflecting hesitation). On the other hand, being told that their conversational partner was real, rather than simulated, increased egocentric responding, presumably because participants shifted the burden of ensuring mutual understanding to the partner, who was the one requesting information and shared the same goals in the task.

Attributional cues about the partner influence not only how people interpret spatial descriptions (Duran, Dale, & Kreuz, 2011; Tversky & Hard, 2009), but also how they produce them. For example, when describing arrays to an imaginary (vs. real) partner, speakers are more likely to use partner-centered descriptions and less likely to use egocentric ones (Schober, 1993). Even minimal attributional cues, such as an imaginary partner's familiarity with the environment, alter speakers' description strategies appropriately: speakers planning routes in a familiar environment for an unfamiliar, imaginary addressee (vs. for themselves) used more words and details, navigating along fewer, larger and more prominent streets, and referring to more landmarks for orienting (Hölscher et al., 2011).

Together, these studies demonstrate that people consider their collective effort and, on the basis of attributions they make about their partner's ability to contribute to the task, adapt their production or interpretation of spatial descriptions. A number of cognitive constraints and social cues contribute to forming these attributions: their misalignment from their partner, their own and their partners' spatial ability, whether they can interact freely with their partner, and whether they believe their partner is real, familiar with the environment, or aware of their viewpoint. As a result, they expend considerable effort to adopt their partner's perspective when conveying spatial information to an imaginary partner (Hölscher et al., 2011; Schober, 1993), when feedback is constrained (Shelton & McNamara, 2004), when their partner has worse spatial abilities (Schober, 2009) or doesn't know their viewpoint (Duran et al., 2011, Exp. 2; Shelton & McNamara, 2004). On the other hand, they don't invest as much effort in adopting the partner's perspective and instead rely on the partner to request clarifications as needed (see Clark, 1996; Clark & Krych, 2004), when interacting with a real (Schober, 1993) or assumed to be real partner (Duran et al., 2011, Exp. 3).

Nonetheless, investigations of spatial perspective-taking in collaborative tasks, especially those focusing on the production of spatial descriptions, have usually sought evidence for people's perspective choices in linguistic behavior without considering the underlying spatial memory representations that support perspective-taking. It is therefore not clear whether the partner's viewpoint can be represented in memory—or rather, it is not clear *under what attributional cues* it can be represented in memory.

One study by Shelton and McNamara (2004) shed some light on this question by examining both speakers' choices in their spatial descriptions and their subsequent memory performance. In this study, after describing an array to their partner, speakers were more accurate to make judgments from perspectives aligned with the one that their partner had previously occupied than from other perspectives. Speakers used mostly partner-centered descriptions regardless of the degree of misalignment from their partner, since they were explicitly instructed to describe arrays from the partner's perspective, with an arrow cueing them of that perspective throughout the description. Additionally, interactions were constrained, with addressees not knowing where the speakers were relative to the display and not being allowed to provide spoken feedback. Since the experimental instructions and constraints on the partner's ability to contribute were intended to encourage speakers to adopt their partner's perspective in descriptions, it's not altogether surprising that speakers represented their partner's perspective in memory. Evidently, when situational constraints explicitly emphasize the partner's viewpoint, it *can* be used as the preferred direction around which to organize information in memory. But in the absence of such explicit emphasis on the partner's perspective, it's not clear whether people spontaneously use it as a preferred organizing direction in memory. In our study, we address directly whether the partner's viewpoint, when available but not explicitly emphasized, is a sufficiently compelling attributional cue to influence people's memory representations.

What is also unclear is the extent to which people rely on their spatial memory representations (and their preferred organizing direction) when describing spatial information. Speakers routinely access spatial memory representations off-line to describe to their partner previously experienced environments, but previous collaborative studies (including Shelton and McNamara's, 2004) have focused only on situations where spatial information is visually accessible to speakers. Thus, is not clear whether, when describing previously encoded spatial relations to a partner, speakers adopt the organizing direction of their memories as the preferred perspective of their descriptions or rely on perceptual information about their partner, available during the interaction.

The present study

In this work, we ask not only whether people spontaneously incorporate their partner's viewpoint in spatial memory representations, but also whether the organization of spatial representations influences their subsequent linguistic descriptions. To do so, we adapted Shelton and McNamara's (2004) design in a number of ways. First, whereas in Shelton and McNamara participants learned spatial arrays while describing them, we dissociated the learning of arrays from their description to manipulate what was known in advance about the partner's viewpoint. Manipulating participants' communicative intent (whether they knew they would be conveying spatial information to a partner) and the availability of the partner's viewpoint (whether they knew it in advance or not) allowed us to assess how attributions about their partner's ability to contribute to the subsequent collaborative task would affect how they encoded spatial information in memory. Additionally, dissociating the learning of spatial arrays from their description and thus having participants describe arrays from memory rather than from vision (cf., Schober, 1993, 1995, 2009; Shelton & McNamara, 2004) enabled us to examine the extent to which speakers rely on the organization of their spatial memories when describing spatial information.

Secondly, unlike Shelton and McNamara (2004), we did not "force" participants to adopt a particular perspective either when learning an array or when describing it; in fact, we did not constrain participants' interactions in any way. As we have seen in the previous section, people are more likely to invest in adopting the partner's perspective when they cannot exchange spoken feedback or they believe that their partner does not know their viewpoint. In the absence of such constraints, we could assess whether the partner's viewpoint is a sufficiently strong cue on its own to affect spatial memory. Specifically, we wanted to determine whether under such circumstances, people would use the partner's viewpoint as a preferred organizing direction, whether they would represent it in memory but not use it as an organizing direction, or whether they would ignore it altogether.

Additionally, unlike some studies on spatial perspective-taking, in our study partners were misaligned by both orthogonal (e.g., 90°, 180°) and oblique offsets (135°). Orthogonal perspectives (at 90°, 180°, and 270°) may be privileged, insofar as they are aligned with the canonical axes of the speaker (see McNamara, 2003). They may be therefore relatively easily adopted or maintained, which could account for speakers' linguistic choices in studies where partners were misaligned exclusively by orthogonal offsets (e.g., Schober, 1993, 1995, 2009; Mainwaring et al., 2003). Also, whereas other spatial perspective-taking studies have used simplistic (often 2-object) configurations (e.g., Duran et al., 2011; Mainwaring et al., 2003; Schober, 1993), we used sufficiently complex configurations of objects that would allow us to assess the preferred direction with which people organized object relations in memory.

In our study, pairs of participants performed series of tasks repeated across three blocks. In each block, one participant, the Director, studied a table-top array of real objects and later described it from memory to the other participant, the Matcher, who reconstructed the array based on the Director's descriptions. While studying the array, Directors in the first block didn't know anything about the upcoming description to a partner (No Intent condition), and in the subsequent blocks either knew about the description without knowing the Matcher's viewpoint (Intent condition) or knew about both the description and the Matcher's viewpoint (Co-Presence condition). After studying an array, Directors' memory of it was assessed through two spatial memory tasks. The first task involved *judgments of relative direction* (JRDs), in which participants were asked to imagine a specific location and orientation and then to point to another object from that perspective. The second task involved reconstructing the array by indicating the position of each object on a grid circle representing their working area. After the memory tasks, Directors described the array from memory to Matchers, who reconstructed the described array with the same objects at a separate workstation. During the description, partners were offset by 90°, 135°, or 180°.[1]

Our predictions were as follows:

1. The partner's viewing perspective would influence the Directors' performance in the memory tasks only when it had been available in advance. Therefore:
   a. When Directors did not know their Matcher's viewpoint while studying the array, they would represent information from a direction aligned with their learning viewpoint, given the lack of an intrinsic structure in our arrays. Thus, in the No Intent and Intent conditions we expected facilitation of the Director's own viewpoint (0°).
   b. On the other hand, when Directors knew the Matcher's viewpoint while studying the array, in the Co-Presence condition, we expected that spatial

[1] After the description, the Matchers' memory of the array they reconstructed was also assessed, through JRDs and array drawings. In this paper, we examine only the Directors' memory performance and linguistic descriptions, as our main research question focuses on Directors' adaptation toward their Matchers.

judgments from headings aligned with the Matcher's viewpoint would show distinct processing relative to other headings. Such distinct processing of the Matcher's viewpoint could occur in conjunction with (rather than in place of) facilitation of the Director's viewpoint. Activating multiple perspectives before selecting one has been observed when interpreting spatial descriptions in both social tasks (e.g., activating both the egocentric and partner-centered perspective, Duran et al., 2011) and non-social ones (e.g., simultaneously activating viewer-centered, object-centered, and environment-centered perspectives, Carlson, 1999; Carlson-Radvansky & Irwin, 1993; Carlson-Radvansky & Logan, 1997; Taylor, Naylor, Faust, & Holcomb, 1999).

2. The extent to which Directors represented the partner's known viewpoint in memory and used it in their descriptions would depend on the difficulty of adopting that viewpoint.

A caveat, here, is that there are different views on what constitutes difficult perspective-taking in collaborative spatial tasks. Some findings suggest that perspective-taking involves mentally rotating to adopt the partner's viewpoint (Duran et al., 2011), such that the further the rotation is from one's own viewpoint the more difficult it is (see also Michelon & Zacks, 2006; Presson & Montello, 1994). Alternatively, the cognitive cost of perspective-taking may depend, not on the degree of mental rotation, but on whether the adopted viewpoint is aligned with directions orthogonal to the preferred direction (e.g., McNamara, 2003). This would suggest that the oblique offset of 135° would be more computationally demanding than the larger offset of 180°, which is aligned with the Directors' canonical axes. Our findings can clarify the process underlying adopting the partner's perspective by indicating when spatial perspective-taking would more costly for speakers.

In either case, insofar as partners share responsibility for mutual understanding and try to minimize the collective effort of themselves and their partner (Clark, 1996; Clark & Krych, 2004; Clark & Wilkes-Gibbs, 1986), we specifically expected that:

a. Directors would not invest in representing the Matcher's viewpoint in memory upon assessing that adopting it difficult, and would opt to represent spatial information egocentrically (especially since they could freely interact with them later). Thus, the extent to which advance information about the partner's viewpoint is incorporated in memory should depend on the misalignment between partners.
b. In selecting the perspectives of their descriptions, Directors wouldn't merely rely on the memory representations they initially constructed, but would also use perceptual information available in the communicative situation (i.e., the degree of misalignment between partners). This is consistent with findings that, people don't always adhere to their memory's organizing direction when there is a conflict between their memory representation and perceptual evidence (e.g., when having to describe objects from a new viewpoint), but instead use both sources of information to select the perspective of their descriptions (Li et al., 2011, Exp. 5).

In general, we expected that when perceptual information indicated that perspective-taking would be demanding for Directors, they would consequently use more egocentric spatial expressions (perhaps with their partner's joint agreement); otherwise, they would use more partner-centered ones. But we also predicted an interaction between advance knowledge and perceptual information about their partner's viewpoint: since knowing the partner's viewpoint in advance could help speakers assess early on the cognitive demands of the task on either partner, it could enable them to plan the perspectives of their descriptions more strategically.

Method

Design

Across the three blocks, we manipulated the degree to which Directors knew about their Matcher's viewing perspective while studying the array (i.e., the salience of the partner's perspective) as well the misalignment between the two participants during the description phase. Across the three blocks, during the study phase, Directors: (1) didn't know that they would have to describe the array to a Matcher (No Intent condition), (2) knew that they would have to describe they array to a Matcher, but did not know what the Matcher's viewpoint would be (Intent condition), or (3) knew that they would have to describe the array to a Matcher and also knew what the Matcher's viewpoint would be since the Matcher was co-present in the room (Co-presence condition). Misalignment for a given array was 90°, 135°, or 180°.

Misalignment and array identity were fully counterbalanced across pairs of participants. For partner salience, Directors always studied the first array in the No Intent condition, with the remaining conditions counterbalanced across pairs of participants to control for practice or carry-over effects: half the pairs of participants studied and described arrays in the order *No Intent–Intent–Co-presence*, whereas the remaining pairs in the order *No Intent–Co-presence–Intent*, across the three blocks. This gave rise to 18 combinations of the three main factors, each of which was assigned to a pair of participants. Thus, partner salience, misalignment and array identity were within-participant factors, and the order of partner salience was a between-participants factor.

Participants

Thirty-six college-age students (18 pairs) participated in exchange for research credit for a psychology course or for payment. Half of the participants participated as Directors (9 female and 9 male) and the remaining half as Matchers (9 female, 9 male). Of the 18 Director–Matcher pairs, 6 were female–female pairs, 6 were male–male pairs, and 6 were mixed-gender pairs (with a female Director in 3). Except for four pairs, participants were not previously

Fig. 1. One of the three seven-object arrays used (including a battery, flashlight, bowl, orange, yoyo, button and vase).

acquainted; the memory performance and linguistic descriptions of the previously acquainted pairs did not differ reliably from the rest. All participants were native speakers of Cypriot Greek.

Materials

Arrays

Configurations of real objects were displayed on a 70 cm-diameter circular table. Three arrays were used, one in each block of the experiment. Each array involved seven common objects that lacked intrinsic front–back and left–right axes; as a result, most objects were cylindrical, spherical, hemispherical, or otherwise symmetrical in shape (see Fig. 1 for an example of an array configuration). Each of the three configurations were arranged to appear randomly configured, without an axis of symmetry or clear directional structure.[2]

Set-up

Directors studied arrays of objects and subsequently described them to their Matchers in one laboratory room (the study and description room). JRDs and array drawings were performed in an adjacent room (the testing room) to ensure that participants used an enduring off-line spatial representation as opposed to a transient sensorimotor representation of the arrays (see Avraamides & Kelly, 2008 for a discussion).

In the study and description room, two identical 70 cm-diameter circular tables were separated by a barrier (113 cm tall), preventing participants from seeing each other's working areas while allowing them to see each other's faces. To the left of the Director's chair, which was always at the same position, was a computer with a joystick, used in the practice phase of JRDs, and a webcam that video-recorded the Director during the study and description phases. An HD camera behind the Matchers' table offered a view of the Matcher's progress in reconstructing the array during the description phase. The video cameras yielded digital video–audio files for each pair for later offline analysis of the Directors' descriptions. Multimodal information from the videos, including the Directors' gestures and the Matchers' progress in reconstructing the layout, was relevant to categorizing spatial expressions that might have been ambiguous from transcripts alone. Fig. 2 illustrates the set-up in the learning room. The set-up in the testing room involved two computers with joysticks.

General procedure

Participants were randomly assigned to the roles of Director and Matcher while controlling for gender. When the Director arrived at the lab, Experimenter 1 (E1) obtained informed consent for participation; participants could also sign an optional release form for use of their video and audio data for scientific purposes. E1 explained to Directors that they would have to study arrays of real objects, memorizing the objects' position for later memory tests. Specifically, Directors were told that in addition to the memory task, they might have to perform some additional tasks but were not told explicitly that they would have to describe the arrays to another participant. Directors then completed a practice phase, during which they studied an array of four objects without a time limit to memorize it. Directors practiced performing JRDs, first through pointing with the hand and with visual access to the array, and then through pointing with a joystick for trials presented on a computer and without visual access to the array. On a JRD trial, participants are instructed to imagine being at one location (station object) facing a second (orienting object), and from this imagined heading to point to a third, the target (e.g., *Imagine being at the vase, facing the orange. Point to the button.*).

Once Directors completed the practice phase, they studied the array for the first experimental block without knowing they would later have to describe it to another participant (*No Intent* condition). When Directors indicated having memorized the array, E1 verbally administered six JRD trials while Directors wore a blindfold that prevented visual access to the objects. If needed, Directors could remove the blindfold to study the array further. Once E1 ensured that Directors had learned the array, they moved to the testing room to complete JRDs and the drawing task for that array.

In the meantime, the Matcher, who was scheduled to arrive 20 min after the Director, was met by Experimenter 2 (E2), who obtained consent, and informed Matchers that another participant would be describing arrays of objects to them, which they would have to reconstruct and memorize for subsequent tests. For their practice phase, Matchers sat at their table at a 90° offset from E2, who sat at the Director's table, and were given four objects to practice reconstructing a configuration described by E2.

[2] We used configurations of arrays that lacked an axis of symmetry since people consider the array's intrinsic structure when determining the preferred direction around which they organize information in memory (e.g., Li et al., 2011; Mou & McNamara, 2002; Shelton & McNamara, 2001). In order to examine whether the partner's known viewpoint is a sufficiently strong cue to influence the organization of spatial memories (and subsequent spatial descriptions), we eliminated competing cues (e.g., the arrays' intrinsic structure) by constructing arrays with a seemingly random configuration.

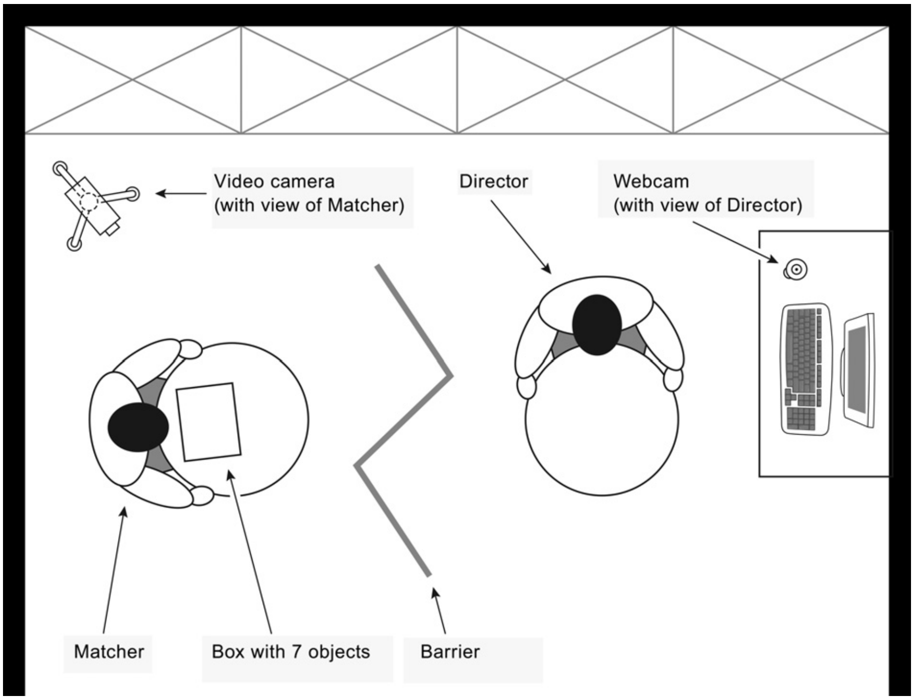

Fig. 2. Set-up in the study and description room, showing the Director's and Matcher's working stations, and the locations of recording devices. In this example of a description phase, the Matcher is at a 90° offset from the Director.

E2, adopting the role of Director, described the four objects of the practice array (without having them in front of her and using the same script of descriptions with every Matcher). E2's descriptions involved a combination of descriptions that took explicitly E2's perspective (e.g., *in front of me*) and the Matcher's perspective (e.g., *to your right*), descriptions that took implicitly the Matcher's perspective (e.g. *the glue is about 40 cm below the soap*), and descriptions that were neutral (e.g., *the soap, the shell, and the perfume bottle form a right angle*; *the whole shape is a trapezoid*). Once E2 confirmed that Matchers' had reconstructed the practice array correctly, Matchers studied it without a time limit and then practiced performing JRDs, first through pointing by hand and with visual access to the objects, and then with a joystick on trials presented on the computer, without visual access to the objects. After completing this practice phase, the Matcher and E2 waited for the Director and E1.

With their consent, Directors returned to the study and description room to describe to Matchers the array they had previously studied and on which they had just been tested. Directors sat at their initial position and Matchers at the assigned offset for the given block. The instructions to both participants for the description phase emphasized that they could interact freely and that they should reconstruct the array so that, given the Director's viewpoint, objects be translated to the Matcher's table (i.e., not rotated by the Matcher's offset). Directors were not restricted in how they could describe the objects to the Matchers: they were told that they were free to describe the objects from their own perspective, their Matcher's perspective, focus on the relationships between objects, or a combination of these options. Similarly, Matchers were not restricted in terms of the kind of feedback they could provide. Their only restriction was that Directors could not look over the barrier that separated them to monitor how Matchers reconstructed the configuration on their table. The experimenters turned on the cameras and left the room during the description phase.

After the participants completed the description phase, E2 ensured that Matchers had memorized the reconstructed array through six verbally administered JRDs, while Matchers wore a blindfold that blocked visual access to the array. Matchers were then taken by E2 to the testing room to complete JRDs and the array drawing task. Before proceeding to the next block, the experimenters took a digital picture of the reconstructed objects on the Matcher's table from a bird's eye view.[3]

This sequence of the Director's study, the Director's testing, the description, and the Matcher's testing phases was repeated in two more blocks, which differed in the salience of the Matcher's perspective during the study phase and in the misalignment between partners during the description phase. On the final block, when participants completed their last phase for their role (the description phase for the Director and the testing phase for the

[3] The digital photographs provided the veridical positions of the objects for the array of each Matcher. In other analyses, we use the degree of distortion of the Matchers' reconstructions relative to the arrays the Director had studied to assess the effectiveness of communication strategies between partners.

Matcher), they were given a brief questionnaire about how well acquainted they were with the other participant and were debriefed and compensated with 20 Euros for their time, if paid. Experimental sessions took about 2 h and 30 min.

Below we provide more detail about the tasks of testing phase.

Judgment of relative direction

On each trial, participants first read a statement in the form "*Imagine being at x, facing y*", pressed a button on a joystick once they adopted that heading, and then responded to a statement like "*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. By tapping upon inter-object relations, JRDs allow us to determine what preferred direction participants use to organize the spatial relations in memory (e.g., Kelly, Avraamides, & Loomis, 2007; Kelly, Avraamides, & McNamara, 2010; Shelton & McNamara, 1997). For each array, 48 JRD trials were presented individually as text on a computer screen at a comfortable distance from the participants. The trials included eight imagined heading (0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°) and their order was randomized. In selecting the trials, we aimed to represent equally each combination of station and orienting objects corresponding to each heading, balancing the number of trials with right and left responses, and representing objects comparably across positions (as station points, orienting objects and targets).

The Directors' orientation and response latencies were assessed.[4] Orientation latency was defined as the time from the offset of the instruction to adopt an imagined perspective to the press of the joystick button to indicate that the imagined perspective was adopted. Response latency was defined as the time from the offset of the instruction to point to the target object to the press of the button to log the response after deflecting the joystick.

Array drawing

The array drawing task required participants to indicate the position of each object on a gridline circle depicting the display table, allowing us to assess participants' memory for relative positioning of objects and for systematic biases (e.g., Friedman & Kohler, 2003). Participants were given 20 cm-diameter grid (with 1 mm lines) and seven circular transparent markers, each labeled with a name of an array's objects and a dot in the center representing the object's center. Participants were asked to imagine that the circle represented their table and the labels represented the objects whose position they had studied and to reconstruct, as accurately as possible, their configuration. Afterwards, the experimenters marked the position of the dot for each marker along with the object's label, and noted with an arrow at the bottom the participant's viewing perspective while drawing the array.

We performed bidimensional regression analyses to compare participant's drawings to the actual object configurations. The measures of interest here were the rotation parameter (θ) and the bidimensional regression coefficient (*BDr*). The rotation parameter indicates the extent of rotating the drawn configuration relative to the viewed array, thus capturing a potential systematic bias in Directors' drawings. *BDr* estimates the goodness-of-fit between the drawings and the actual coordinates of the arrays, capturing unsystematic error in reconstructions when systematic biases are accounted for.

Transcribing description phases

For each pair, the three description phases were transcribed in detail, including both the Matcher's and the Director's contributions. The transcripts included annotations of fillers ("ehm" and "ee", Greek-Cypriot equivalents of "um" and "uh"), pauses, interruptions (both self-interruptions and interruptions by the Matcher) and restarts. Instrumental actions performed by the participants (such as the Matcher correcting the location of an object on the table) and non-verbal feedback, such as head nods and facial displays (e.g., frowning to indicate confusion), were also annotated in the transcripts.

Coding the Directors' descriptions

Spatial expressions

In each transcript, the first author identified and classified spatial descriptions in the Director's contributions. We considered spatial expressions to include (i) locative adverbs, e.g., "to your right" (*dheksia su*), "to my left" (*aristera mu*), "in between" (*anamesa*), "next to" (*dhipla*), (ii) geometric shapes and metrics, e.g., "straight line" (*efthia*), "triangle" (*trigono*), "ninety degrees" (*eneninta mires*), (iii) directional verbs accompanied by a spatial adverb, e.g., "go up" (*pienne pano*), (iv) verbs describing spatial relationships or the movement of objects, e.g., "move it farther away a bit" (*apomakrine to llio*), "it sticks out a bit" (*eksehi llio*), "divide the radius of the table" (*na mirasis tin aktina tu trapeziu*), "increase the angles" (*megalos'tes gonies*), and (v) spatial adjectives, e.g., "distant" (*apomakrismeno*). We excluded Directors' spatial expressions that recast a perspective introduced by the Matcher in the preceding turn, either verbatim or in a parallel syntactic form (e.g., M17: "so, for you, it's supposed to be to your right, isn't it?" D17: "no, for me, it's supposed to be in front of me").

[4] We also recorded pointing error in JRD responses—the unsigned angular deviation of the joystick response from the veridical response. We don't report these analyses, as pointing errors were quite high ($M = 67.92°$ $SD = 60.91°$). This was not due to a speed-accuracy tradeoff. Within participants, latency-error correlations did not differ significantly from zero, for neither orientation latency (t (17) = −1.19, p = .25) nor response latency (t (17) = 1.26, p = .23). And between participants, error rates were not correlated significantly with either orientation latency (Pearson's r = .15, p = .56) or response latency (Pearson's r = .04, p = .89). Instead, high pointing errors are likely an artifact of joystick mechanics biasing responses away from the intended bearing. Because the joystick shaft moves within a square base, reproducing angles at diagonals (i.e., 45°, 135°, 225°, and 315°) is easier than other angles. In fact, as some other work from our lab suggests, angles at diagonals may function as attractors of responses. The only reliable finding for pointing error was that, relative to the first block, Directors were more accurate when they knew they would be subsequently describing the array to a partner: No Intent vs. Intent: F (1,16) = 16.56, p < .01; No Intent vs. Co-Presence: F (1,16) = 2.64, p = .11.

We adapted Schober's coding scheme (1995, 2009) and classified spatial expressions in the Directors' turns as adopting:

(a) the Director's perspective, e.g., "in front of me is the bracelet" (*mprosta mu en to vrahioli*)
(b) the Matcher's perspective, e.g. "the battery is to your right" (*i bataria en sta dheksia su*)
(c) a Neutral perspective capturing inter-object relations independent of either participant's viewpoint, e.g., "it's closer to the ashtray" (*en pio konta pu to tasaki*) or "they form a triangle" (*schematizun trigono*)
(d) a perspective other than the Director's or Matcher's (Other heading), e.g., "say you are at the vase and directly in front of you is the orange" (*pes oti ise sto vazo dje akrivos mprosta su en to portokali*).
(e) a perspective that was true for both the Director and the Matcher (Both-centered), e.g., "in between us" (*metaksi mas*).
(f) an Environment-centered perspective, relative to objects or other aspects of the extrinsic environment, e.g., "toward my purse" (*pros ti tsanta mu*), "towards the bookcase" (*pros ti vivliothiki*)
(g) an Object-centered perspective that was relative to the intrinsic axes of objects, e.g., in reference to the orange, "and its belly, let's say..." (*dje i djilia tu as pume*...)
(h) an Ambiguous perspective for expressions that could be interpreted as involving more than one of the above perspectives

Two blocks of the corpus (the last block of Director 7 and the first block of Director 8) were excluded from coding because participants, despite instructions, described those arrays as if the arrays had been rotated in alignment with their Matcher. Person-centered expressions in these blocks were uncodable because, by rotating the array, the Directors and the Matchers' perspectives became indistinguishable.

Note that person-centered expressions were often implicit, and did not involve the use of personal pronouns (e.g., "it's on the left", *en aristera*). In fact, 58% of Director-centered and 42% of Matcher-centered spatial expressions were implicit. To determine the implicit perspective of these cases (as well as in other ambiguous cases), coders considered multiple sources of information, including: (i) the known configuration of objects that Directors were describing, (ii) the misalignment between participants for that block, (iii) the previous and following discourse context, with special attention to the person-centered perspective or system that partners may have already agreed on, (iv) the Directors' gestures, (v) the Matchers' progress in reconstructing the array (especially during misunderstandings), and (vi) the Director's drawing of the array from the associated testing phase (particularly to establish if Directors were misremembering the array, in cases where descriptions seemed inaccurate).

Perspective agreement, and preferred perspective

In addition to the distribution of spatial expressions, we examined:

(i) Whether pairs had explicitly agreed on the perspective from which Directors would describe the array early in their interaction, before Directors finished describing the location of the first object.
(ii) The Director's overall preference in a given block for a person-centered perspective. For each block, we computed the proportions of Director-centered and Matcher-centered expressions, and classified Directors as having a particular preference for that block if proportions exceeded .70 for either category. Blocks scoring below .70 were classified as having a mixed perspective.

Reliability

To assess reliability for the classification of spatial expressions, we had a second coder (blind to the partner salience condition[5]) redundantly code approximately 22% of the corpus (dialogues from 4 pairs), resulting in a total of 840 judgments. The two coders made identical classifications of spatial expressions 93% of the time, Kappa = .90, $p < .001$, exhibiting almost perfect agreement (see Landis & Koch, 1977). Diverging coding decisions were resolved by discussing them until consensus was reached among the coders.

Analyses

Judgments of relative direction

For the JRD task, partner salience, misalignment, heading, and array identity were within-participant factors, and the order of partner salience was a between-participants factor. Array identity will not be considered further in the reported analyses, as performance across arrays did not differ significantly in terms of orientation latency ($p = .48$) or response latency ($p = .54$). Therefore, unless indicated otherwise, ANOVAs comparing performance across partner salience conditions had partner salience and heading as within-participants factors and partner salience order as a between-participants factor, while ignoring misalignment. Effects on misalignment were assessed for each partner salience condition separately, with ANOVAs that had misalignment and heading as within-participants factors and partner salience order as a between-participants factor.

We used planned contrasts to assess performance across partner salience conditions. Note that we expected that, in the absence of advance information about the Matcher's viewpoint, Directors' preferred direction of encoding the array would be largely determined by their egocentric experience during study. To assess this, we examined a pattern whereby Directors' performance would be facilitated in their encoding (0°) heading, would decrease linearly as imagined headings deviated from this preferred heading, but also be facilitated at the counter-aligned heading (a pattern consistent with previous findings e.g., Greenauer & Waller, 2008; Hintzman, O'Dell, & Arndt, 1981; Roskos-Ewoldsen, McNamara, Shelton, & Carr,

[5] Coders could not be blind to the condition of misalignment between partners, as this information was critical for classifying implicit person-centered perspectives.

1998). We represented facilitated performance by fitting planned contrasts with weights −1.75, −0.75, 0.25, 1.25, 0.25, 1.25, 0.25, −0.75 with the minimum at the 0° heading (see also Greenauer & Waller, 2008). We examined effect sizes by evaluating the percent of variance associated with imagined heading accounted for and unaccounted for by this contrast (see Keppel & Wickens, 2004).[6]

Given our prediction that when the Matcher's viewpoint was known in advance, headings aligned with the Matcher would show distinct processing, for the Co-Presence condition, we used planned contrasts comparing the known Matcher's heading with the Director's encoding heading and with the mean of the remaining headings.

Array drawings

We first used Friedman and Kohler's (2003) bidimensional regression tool and recommendations to compare participants' drawings to the studied array. We applied a Euclidean transformation to the veridical array coordinates in order to extract the variables of interest, the rotation parameter (θ) and bidimensional regression coefficient, for each participant's drawings. Then, for θ, we asked whether, for each group of partner salience, there was a significant bias of rotating the drawn array. To examine this, we computed confidence intervals around the mean angle for each salience condition using circular statistical methods, given the angular nature of these data (Upton, 1986). For the No Intent and Intent conditions, where the Matcher's perspective was not known at the time of testing, we did not expect such a bias and thus anticipated the confidence interval of θ to include 0°. For the Co-Presence condition, where the Matcher's perspective was known in advance, we hypothesized that θ may deviate from 0°. To compare the three conditions, we used the Mardia–Watson–Wheeler nonparametric test because the rotation parameters in the No Intent condition were bimodally distributed, violating the assumption that all samples were drawn from populations with a von Mises distribution (see Batschelet, 1981).

For *BDr*, we first Fisher-transformed individual bidimensional regression coefficients (see also, Friedman & Montello, 2006), and then analyzed these normalized coefficients (with ANOVAs with partner salience and misalignment as within-participants factors) to determine whether distortion in the relative positioning of objects differed when Directors knew in advance their Matchers' perspective, and whether the misalignment between the Directors' and Matchers' known perspective differentially affected distortions in the drawn arrays.

Spatial expressions

For the Directors' descriptions, we performed ANOVAs on the proportions of the different types of spatial expressions. The type of spatial expression, partner salience, misalignment and array identity were within-participant factors, and the order of partner salience was a between-participants factor. Array identity will not be considered further, since the Directors' choices of spatial expressions did not differ significantly across arrays ($p = .97$). Main effects and interactions with the order of partner salience are not reported unless significant.

Results

Directors' judgments of relative direction

We first examined the Directors' spatial memory representations, as reflected in their performance in the JRD task. Prior to analyses, outlying latencies (defined as latencies shorter than .5 s and longer than 60 s) were removed, resulting in .19% of trials being discarded for orientation latencies and 2.12% of trials for response latencies.

Orientation latency

As expected, when Directors didn't know their Matcher's subsequent viewpoint in advance, the misalignment between partners didn't influence their orientation latencies (in the No Intent condition $p = .70$, in the Intent condition, $p = .46$; see Table 1). In the No Intent and Intent conditions, Directors' orientation latencies showed facilitation for their encoding viewpoint (0°): in these two conditions combined, the Directors' orientation latencies differed significantly across imagined headings, $F(7,112) = 3.38$, $p < .01$ (assessed by an ANOVA on mean orientation latencies of the two conditions, with heading as a within-participants factor and partner salience order as a between subjects factor) and were described adequately by the planned contrast with 0° as the preferred heading, $F(1,17) = 5.82$, $p < .05$. This planned contrast accounted for 21.22% of the variance associated with the imagined heading, leaving a non-significant amount of variance unaccounted for ($p = .47$). Fig. 3a and b illustrate that orientation latencies in the No Intent and Intent conditions increased linearly as headings deviated from 0°, with the exception of 180°, which also showed facilitation.

As Fig. 3c shows, orientation latencies across headings patterned differently in the Co-Presence condition than the other conditions. To understand this pattern better we considered performance across the three levels of misalignment for the Co-Presence condition (misalignment did not affect orientation latencies overall, $p = .96$). When Directors knew their Matcher would be offset by 90° or 135°, they were slower to orient to headings aligned with their Matcher relative to their own, $F(1,8) = 6.98$, $p < .05$, and marginally so relative to other headings, $F(1,8) = 3.95$, $p = .08$ (see Fig. 4a and b). This wasn't the case when Directors knew their Matcher would be counter-aligned with them (see Fig. 4c): at the180° offset, their latencies to orient to headings aligned with the Matcher did not differ reliably from either those aligned with their own ($p = .34$) or other headings ($p = .31$).

Overall, Directors were faster to orient to imagined headings after the first block, when they knew they would be subsequently describing the array to a Matcher. In the

[6] The percentage of the variance (un)accounted for is a more meaningful way of evaluating the planned contrast than *F*-values, since the contrast is inherently directional whereas the *F*-test is not. Patterns of data that depart greatly from the contrast weights may still be significant according an *F*-test, so determining whether these departures occur at chance levels (i.e., whether the unaccounted for variance is non-significant) is informative.

No Intent condition Directors took 8.77 (SD = 6.98) s to orient to a particular heading, whereas they took an average of 7.52 (SD = 6.16) s in the Intent and 7.79 (SD = 5.88) s in Co-Presence conditions. Performance in these latter conditions differed from the No Intent condition (Intent vs. No Intent: F (1,16) = 3.95, p = .06, Co-Presence vs. No Intent: F (1,16) = 4.53, p < .05). These differences are consistent with an effect of practice (linear trend across blocks, F (1,17) = 6.09, p < .05), which is further corroborated by the interaction between partner salience and partner salience order when contrasting the Intent and Co-Presence conditions, F (1,16) = 5.14, p < .05. In the *No Intent–Intent–Co-Presence* order, Directors were faster to orient to imagined headings in the Co-Presence condition in the third block than the Intent condition in the second block (7.57 vs. 7.93 s). The reverse was true in *No Intent–Co-Presence–Intent* order: Directors were faster to orient to imagined headings in the Intent condition in the third block than in the Co-Presence condition in the second block (7.11 vs. 8.02 s).

Response latency

As expected, when Directors didn't know about their Matcher's subsequent viewpoint in advance, their response latencies were not affected by the degree of misalignment between partners (for No Intent: p = .97; for Intent: p = .46). Like orientation latencies, response latencies showed facilitation along a preferred direction aligned with 0°. For the combined No Intent and Intent conditions, the mean response latencies differed significantly across headings, F (7,112) = 8.50, p < .001. The planned contrast with 0° as the preferred heading described performance adequately, F (1,17) = 20.93, p < .001, accounting for 47.07% of the variance associated with the imagined heading and leaving a non-significant amount of variance unaccounted for (p = .69). As Fig. 5a and b illustrate, response latencies were shorter from the encoding (0°) heading, increasing linearly as headings deviated from it.

When Directors knew their Matcher's viewpoint in advance, response latencies across imagined headings differed significantly, F (7,84) = 4.19, p < .01, but they did not show the same pattern as orientation latencies. Regardless the misalignment between partners, Directors were significantly slower to respond from headings aligned with their Matcher's subsequent viewpoint relative to headings aligned with their own, F (1,12) = 7.42, p < .05, but not relative to other non-egocentric headings (p = .36). As Fig. 6a–c illustrate, a cost of responding from the Matcher's known perspective held numerically only when Directors knew Matchers would be offset by 135° (Fig. 6b); however, response latencies from that known heading did not differ significantly from either the Director's own heading, F (1,4) = 2.87, p = .17, or the remaining headings, F (1,4) = 3.28, p = .14. Instead, Directors' response latencies suggested that they represented arrays from a preferred direction aligned with their encoding viewpoint (see Fig. 5c): the planned contrast representing a preferred direction aligned with 0° was significant, F (1,17) = 15.61, p < .01, accounting for 58.22% of the variance associated with the imagined heading and leaving a non-significant amount of variance unaccounted for (p = .78).

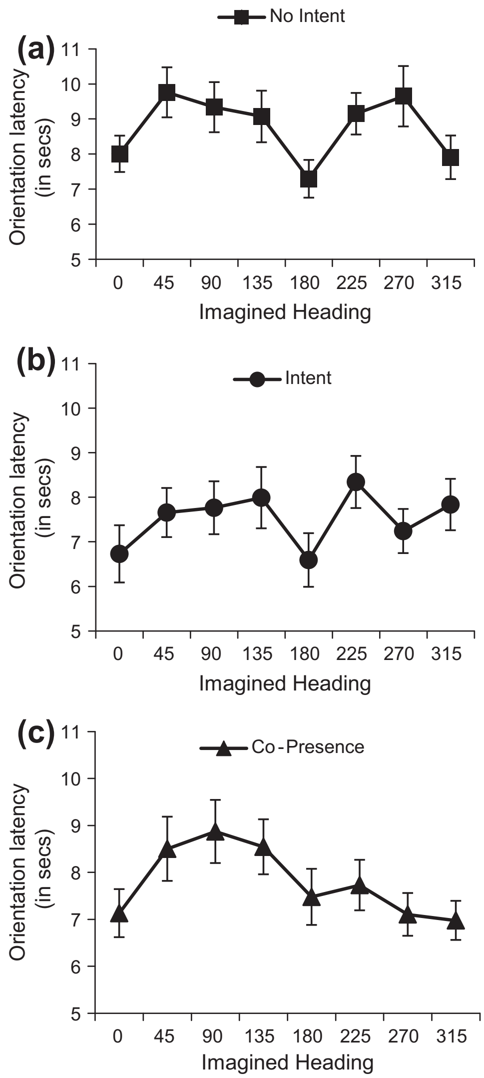

Fig. 3. Orientation latencies (in sec) of the Director across imagined headings, for each of the conditions of partner salience: No Intent (a), Intent (b), and Co-Presence (c). Bars represent standard errors of the mean.

Table 1
Means (and standard deviations) of the orientation and response latencies (in sec) of the Director across partner salience and misalignment conditions.

	90°	135°	180°
Orientation latencies			
No Intent	9.81 (6.94)	7.58 (5.29)	8.93 (8.25)
Intent	6.50 (4.29)	8.79 (7.92)	7.27 (5.51)
Co-Presence	7.56 (6.70)	7.73 (4.63)	8.10 (6.15)
Response latencies			
No Intent	5.62 (4.66)	5.71 (4.87)	6.01 (7.02)
Intent	3.80 (2.99)	4.89 (4.50)	4.57 (4.28)
Co-Presence	4.93 (5.25)	3.90 (2.75)	5.39 (3.56)

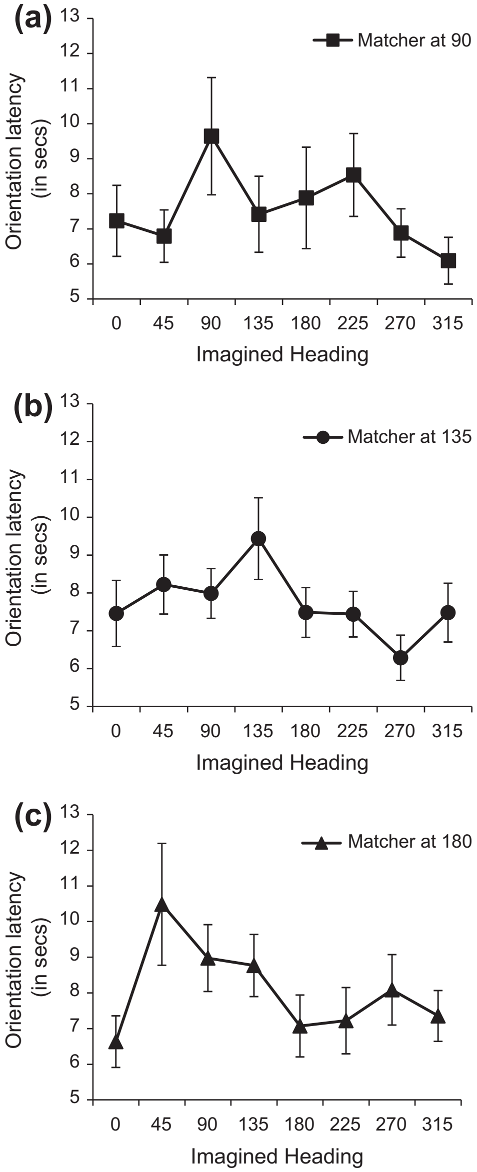

Fig. 4. Orientation latencies (in sec) of the Director in the Co-Presence condition across imagined headings for each of the misalignment conditions: 90° (a), 135° (b), and180° (c). Bars represent standard errors of the mean.

Directors were faster, not only to orient to, but also to respond from imagined viewpoints after the first block, when they knew they would be describing the studied arrays to a Matcher (linear trend across blocks: $F(1,17) = 5.29$, $p < .05$). In the No Intent condition Directors took an average of 5.78 ($SD = 5.62$) s to respond from imagined headings, whereas they took an average of 4.41 ($SD = 3.99$) s in the Intent and 4.72 ($SD = 4.05$) s in Co-Presence conditions. As with orientation latencies, when Directors knew about the subsequent description, whether they knew their Matcher's viewpoint or not, they were faster to respond from an imagined heading than when they didn't know about the description (Intent vs. No Intent: $F(1,16) = 4.93$, $p < .05$, Co-Presence vs. No Intent: $F(1,16) = 5.41$, $p < .05$). Since salience order did not interact with partner salience, faster response times after the first block could be either due to practice or communicative intent.

Directors' array drawings

As we predicted, when Directors did not know their Matchers' viewpoint in advance, there was no evidence of a systematic bias in rotating their array drawings: confidence intervals for the mean rotation parameter in the No Intent and Intent condition included 0°: for No Intent, $\theta = 0.905°$, $r = 0.897$, 95% CI [−16.103, 17.897]; for Intent $\theta = 0.199°$, $r = 0.995$, 95% CI [−2.801, 3.199]. On the other hand, when they did know their Matchers' viewpoint in advance, there was evidence for such a bias: the mean

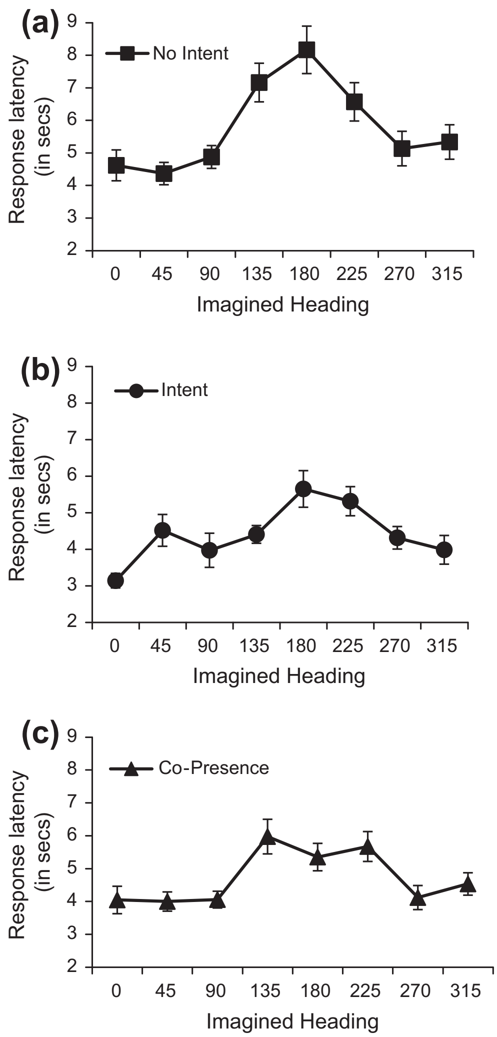

Fig. 5. Response latencies (in sec) of the Director across imagined headings, for each of the conditions of partner salience: No Intent (a), Intent (b), and Co-Presence (c). Bars represent standard errors of the mean.

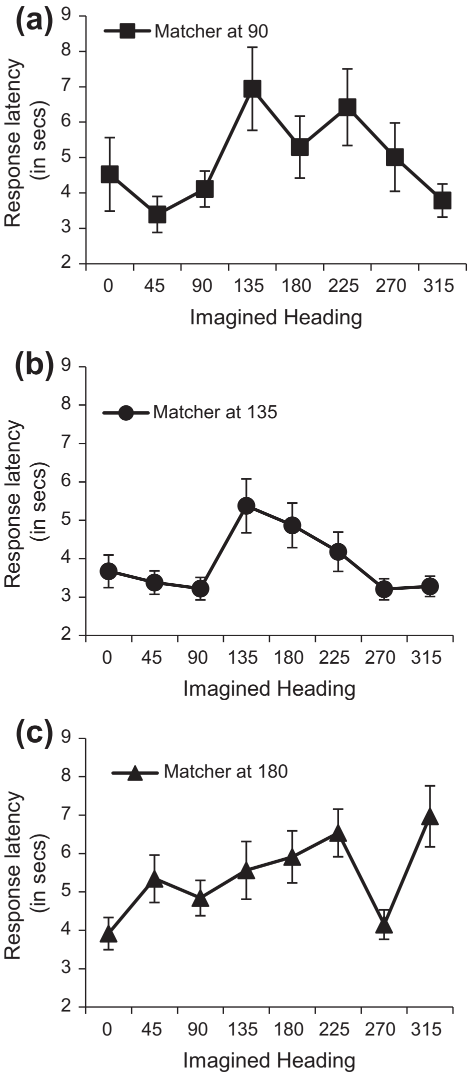

Fig. 6. Response latencies (in sec) of the Director in the Co-Presence condition across imagined headings for each of the misalignment conditions: 90° (a), 135° (b), and 180° (c). Bars represent standard errors of the mean.

rotation parameter was θ = 5.281°, r = 0.991, and its confidence interval did not include 0°, 95% CI [1.281, 9.281]. This indicates that Director's drawings were slightly rotated clockwise, towards the Matcher's known viewpoint. The rotational bias in array drawings differed reliably across the three partner salience conditions: the Mardia–Watson–Wheeler nonparametric test revealed a significant effect of partner salience, $\chi^2_{MWW}(3) = 25.01$, $p < .05$.

Advance knowledge of the Matcher's viewpoint did not, by itself, lead to significantly more distortion in the relative positioning of objects, as assessed by ANOVAs on the Fisher-transformed bidimensional regression coefficient (*BDr*): No Intent vs. Co-Presence: $p = .60$; No Intent vs. Co-Presence: $p = .24$. In fact, array drawings in all conditions of partner salience involved significant distortion in the relative positioning of objects, with the *BDr* differing significantly from 1 (No Intent: $BDr = .96$, $SD = .05$, $t(17) = -3.50$, $p < .01$; Intent: $BDr = .96$, $SD = .03$, $t(17) = -3.37$, $p < .01$; Co-Presence: $BDr = .95$, $SD = .06$, $t(17) = -3.37$, $p < .01$). Nonetheless, when Directors knew in advance that they would be misaligned by 90° from their Matchers, their array drawings were significantly more distorted than in the Intent and No Intent conditions: No Intent vs. Co-Presence 95% CI [.266, 1.146], $p < .01$; Intent vs. Co-Presence 95% CI [.147, 1.027], $p < .05$. Additionally, in the Co-Presence condition, array drawings were marginally more distorted when Directors knew in advance that Matchers would be at 135° than at 180°, 95% CI [−.991, .071], $p = .09$.

Thus, knowing the Matcher's viewpoint in advance led to a reliable rotational bias in array drawings towards the Matcher and affected, in some respects, the distortion of the relative positions of objects.

Directors' descriptions

Distribution of spatial expressions

Directors produced most frequently Neutral expressions in their descriptions (46% of all 3844 spatial expressions), with Director-centered and Matcher-centered expressions next (19% and 23%, respectively), and with Ambiguous and Other-heading[7] expressions together accounting about 11% of the corpus. Because expressions from Both-centered, Environment-centered and Intrinsic perspectives constituted less than 2% of all spatial expressions, we don't consider them further in subsequent analyses. The mean proportion of Neutral expressions was significantly higher than those of every other type (vs. Director-centered: $F(1,51) = 42.85$, $p < .001$; vs. Matcher-centered: $F(1,51) = 58.35$, $p < .001$; vs. Other-heading: $F(1,51) = 323.87$, $p < .001$; vs. Ambiguous: $F(1,51) = 405.65$, $p < .001$). Director-centered and Matcher-centered expressions did not differ reliably in their frequency ($p = .74$), but were both more frequent than expressions from Other-headings, (Director-centered vs. Other: $F(1,51) = 20.25$, $p < .001$; Matcher-centered vs. Other: $F(1,51) = 37.28$, $p < .001$) and from Ambiguous expressions (Director-centered *vs*. Ambiguous: $F(1,51) = 26.81$, $p < .001$; Matcher-centered vs. Ambiguous: $F(1,51) = 48.05$, $p < .001$).

The misalignment between partners affected specifically the distribution of Director-centered or Matcher-centered expressions, rather than the overall distribution of spatial expressions. When Directors were at relatively small offset from their Matchers (90°), they produced reliably more Matcher-centered descriptions than when offset by 135° (28% vs. 17%), $F(1,14) = 17.30$, $p < .01$, and marginally so than when offset by 180° (28% vs. 20%), $F(1,14) = 2.92$, $p = .11$. On the other hand, when they were offset by the oblique 135°, they produced reliably more Director-cen-

[7] Other-heading expressions appear to be unique to our corpus (cf., Schober, 1993, 1995, 2009; Shelton & McNamara, 2004) likely arising from the memory tasks that always preceded descriptions. The format of JRD trials may have served as an available strategy for Directors when describing objects, cueing them to adopt imagined headings other than their Matcher's or their own. Most of the 219 Other-heading expressions in the corpus (71% of them) were produced by three Directors: Other-heading expressions accounted for an average of 24% of the spatial expressions of Director 3, 17% of Director 6, and 19% of Director 16.

tered descriptions than when offset by 90° (25% vs. 16%), $F(1,14) = 11.20$, $p < .01$, and marginally so than when offset by 180° (25% vs. 12%), $F(1,14) = 3.04$, $p = .10$. The distribution of these person-centered expressions at different degrees of misalignment accounts for the overall interaction between the type of spatial expression and misalignment, $F(8,112) = 2.57$, $p < .05$.

To unpack further Directors' preferences for these person-centered expressions, we considered their distribution across the different degrees of misalignment for each condition of partner salience separately (see Fig. 7a–c). As Fig. 7c shows, Directors' preference for egocentric expressions at the 135° was largely driven by the Co-Presence condition. When Directors knew in advance that their Matcher would be offset by 135° they used more Director-centered expressions than when they knew their Matcher would be offset by 90°, $F(1,11) = 5.01$, $p < .05$, and marginally so than when offset by 180°, $F(1,11) = 3.94$, $p = .07$. The preference for Director-centered expressions at 135° in the Co-Presence condition was accompanied by a numerical but not reliable drop in Matcher-centered expressions (proportions of Matcher-centered expressions at 135° vs. 90°, $F(1,11) = 3.44$, $p = .09$, and vs. 180°, $F(1,11) = 3.01$, $p = .11$). Directors' linguistic choices at the 135° offset contextualize their preference for Director-centered over Matcher-centered expressions in the Co-Presence condition (25% vs. 19%).

Directors were also more likely to produce Ambiguous expressions the first time they described an array, in the No Intent condition, than in the Co-Presence condition (7% vs. 4%), $F(1,14) = 9.87$, $p < .01$, or the Intent condition (7% vs. 4%), $F(1,14) = 4.52$, $p = .05$. No other patterns in Directors' spatial expressions were reliable.

Perspective agreement

To contextualize the distribution of expressions reported in the previous section, we also considered when pairs explicitly agreed from whose perspective Directors would describe the arrays. Of the 54 experimental blocks (across the 18 pairs), participants explicitly agreed on the perspective that Directors would adopt in 21 of them. Partners agreed more frequently on a perspective when Directors had already known they would be interacting with a Matcher, after the first block. They agreed on a perspective in only 28% of the blocks in the No Intent condition compared to 44% of the blocks in each of the Intent and in the Co-Presence conditions.

Pairs also agreed more frequently on a perspective when they were offset by the oblique 135°, especially when pairs had known this in advance: in the Co-Presence condition, pairs agreed on a perspective 66% of the time when they knew they would be misaligned by 135° (vs. 33% when they knew they would be offset by 90° or 180°). Within those agreements, partners opted for the Director's (vs. their Matcher's) perspective more frequently when misaligned by 135° (78% of the time) than when misaligned by 180° or 90° (67% and 50% of the time, respectively). In fact, when pairs knew in advance that they would be misaligned by 135°, it was the Matchers who most frequently proposed that Directors should use their own perspective (on 75% of those agreements). Thus, when

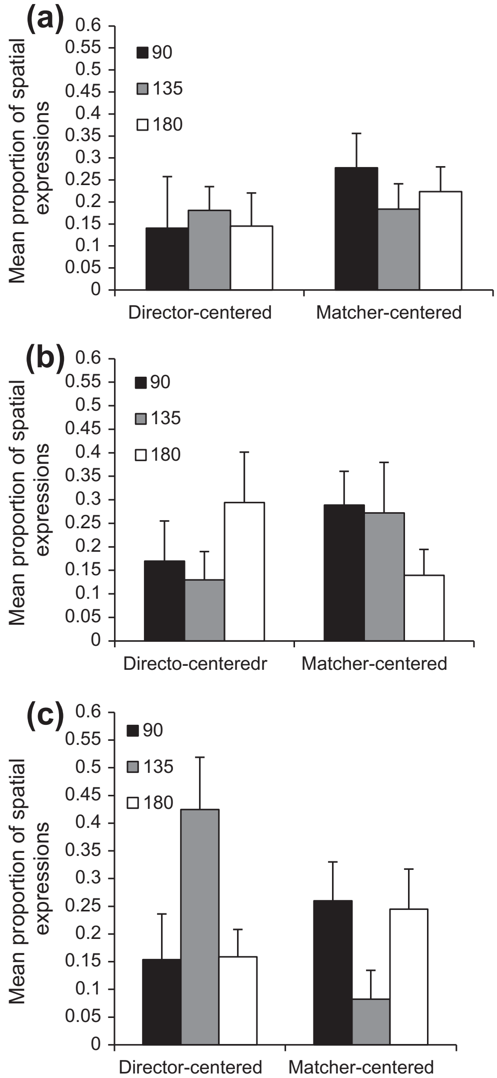

Fig. 7. Mean proportion of Director-centered and Matcher-centered expressions across misalignment conditions, for each of the conditions of partner salience: No Intent (9a), Intent (9b), and Co-Presence (9c). Bars represent standard errors of the mean.

partners had known in advance that they would be misaligned by 135°, they were especially likely to agree on using the Director's perspective, most often following the Matcher's own initiative.

Directors' perspective preference

In half of the 52 blocks for which spatial expressions were codable Directors were classified as having mixed preference for Director-centered and Matcher-centered expressions. Of the remaining 26 blocks, in 16 Directors showed preference for the Matcher's perspective and in 10 for their own. Table 2 shows the distribution of blocks across misalignment and partner salience conditions, in which Directors showed a preference for their own, the Matcher's, or else a mixed perspective. Notably, in 56% of the blocks for which Directors preferred their Matcher's

Table 2
Distribution of blocks, by misalignment and by partner salience, in which Directors showed a preference for their own or their Matcher's perspective (by using more than 70% of such person-centered expressions), or else a mixed perspective.

	Preferred Director's	Preferred Matcher's	Mixed preference
90°	2	9	6
135°	6	4	8
180°	2	3	12
No Intent	1	6	10
Intent	4	5	9
Co-Presence	5	5	7

perspective they were misaligned by 90° from their Matcher, and in 60% of the blocks for which they preferred their own viewpoint they were misaligned by 135° from their Matcher. The difference in the distribution of Directors' preferred perspective across conditions of misalignment was almost significant: χ^2 (4) = 9.23, p = .056. The distribution of preferred perspectives was not affected significantly by the salience of the Matcher's perspective (p = .51).

Synthesis of results

To help formulate a clearer picture of how advance knowledge of a misaligned partner's viewpoint influences memory and behavior, in this section, we summarize and integrate across data patterns from the Directors' memory performance and their descriptions.

A first observation is that knowing the partner's viewpoint in advance impacted various aspects of the Directors' memory performance. When Directors knew their Matcher's subsequent viewpoint while studying arrays, they showed a bias in rotating their array drawings toward their Matcher's viewpoint and showed distinctive processing in JRDs, taking longer to orient to perspectives aligned with their Matcher relative to other non-egocentric perspectives (at least when offset by 90° and 135°). On the other hand, when Directors didn't know their Matcher's viewpoint while studying arrays, they encoded them egocentrically: they did not show a rotational bias in their array drawings, and in the JRD task they showed facilitation orienting to and responding from perspectives aligned with their own.

Directors adapted their descriptions somewhat differently than their memory performance depending on what they knew at the time of study. Whereas in the memory tasks Directors encoded arrays egocentrically when they did not know their Matcher's viewpoint at the time of study (being faster to orient to and respond from perspectives aligned with their own, and not rotating their array drawings), they were no more likely to subsequently describe arrays from their own perspective. And conversely, when they knew the Matcher's viewpoint in advance, Directors were no more likely to subsequently describe arrays from their Matcher's perspective. Instead, the perspective of Directors' descriptions depended largely on perceptual cues available during the description phase: specifically, on the misalignment between partners. When Directors were misaligned by 135° from their Matcher, they were more likely to use egocentric descriptions than at other offsets. And when Directors were misaligned by 90° from their Matcher, they were more likely to use partner-centered descriptions than at other offsets. Similarly, the Directors' overall preference for a particular perspective throughout their description differed according to their misalignment from their Matcher, not according to what they knew at study.

Nonetheless, knowing their degree of misalignment from their Matcher in advance led Directors to strategic perspective choices in their descriptions. Their overall preference of their own perspective at the 135° offset was in fact driven by the Co-Presence condition: when they had known in advance that the Matcher would be offset by the oblique 135°, they were more likely to use egocentric expressions and numerically less likely to use partner-centered ones than at other offsets. This preference of the Director's perspective at this known oblique offset was shared with the Matcher, since pairs in this scenario were especially likely to explicitly agree on using the Director's perspective.

In sum, although Directors adapted their memory representations when they had known their Matcher's viewpoint in advance, they did not simply rely on these representations to determine the perspective of their descriptions. Instead, Directors used perceptual cues available during the description phase (their misalignment from their Matcher), pertinent to their and their Matcher's respective cognitive demands of perspective-taking, to adapt strategically the perspective of their descriptions. Advance knowledge of the Matcher's viewpoint facilitated these strategic choices by enabling pairs to recognize when perspective-taking would be most difficult for Directors (presumably at 135°) and to agree on a perspective that would alleviate their cognitive load.

Discussion

Our findings present a consistent picture regarding how people represent their conversational partner's viewpoint in spatial memory and how, in turn, they use that information during linguistic processing. First, when the partner's viewpoint is available, speakers encode it in spatial representations. However, whether they use it as the preferred organizing direction of their spatial representations depends on the attributions they make about their partner's ability to contribute to the communicative task. Second, when describing spatial information, speakers don't rely exclusively on the organizing direction of their spatial representations, but also use partner-specific information that is perceptually available in the communicative task. Finally, upon considering both perceptual and in advance information relevant to their partner's viewpoint, speakers adapt their spatial descriptions strategically in ways that minimize their collective effort. Our study clarifies when spatial perspective-taking is most demanding for speakers and how they negotiate their description strategies with their partner. We expound on each of these points in the following subsections.

Representing the partner's viewpoint in spatial memory

In our study, in the absence of advance information about their Matcher's viewpoint, when making spatial judgments, Directors were faster to orient to and respond from headings aligned with their own learning viewpoint. As expected, since neither the arrays nor their constituent objects offered intrinsic axes of symmetry as organizing cues, Directors used their own viewpoint to organize spatial relations in memory. However, when Directors knew their Matchers' viewpoint in advance, perspectives aligned with the Matchers' viewpoint showed distinct processing, though this depended on the misalignment between partners. When Directors knew they would be misaligned but not counteraligned with their Matcher (i.e., at 90° and 135°), they tended to be slower to orient to headings aligned with their Matcher. This slower orienting suggests, that, in recalling an episodic trace for their experience from studying arrays (which includes the Matcher's position and orientation at their workstation), Directors incurred a processing cost. This cost may be either due to relating during testing these imagined headings (based on inter-object relations) to the Matcher's external viewpoint, or due to retrieving these headings from a richer representation already linking them to Matcher's viewpoint. Directors also showed a significant bias in their array drawings when they knew their Matcher's viewpoint in advance, rotating their drawings towards the Matcher. At the same time, Directors' response latencies suggest that they represented in memory not only the partner's known viewpoint but also their own, since they were fastest to locate target objects from perspectives aligned with their learning viewpoint. That participants simultaneously represented both viewpoints in memory is compatible with findings that people co-activate their partner's and their own perspective before ultimately selecting one (Duran et al., 2011).

As we have shown, although the partner's spatial viewpoint is encoded in memory when known in advance, it is not necessarily used as an organizing direction for the spatial relationships among array objects (cf. Shelton & McNamara, 2004). Why might this be so? Our study suggests that using the partner's viewpoint as a preferred organizing direction requires strong pragmatic motivation: whether people invest the cognitive effort to organize spatial relations around their partner's viewpoint depends on the attributions they make about their partner's ability to contribute to the task. Our findings, alongside those from Shelton and McNamara's (2004) related study, highlight that people's attributions about their partner's ability to coordinate with them influence whether they incorporate their partner's viewpoint in memory. In Shelton and McNamara (2004), Directors had been explicitly instructed to actively take their Matchers' perspective when they learned the array (while describing it), and were further motivated to adopt that perspective by not being able to freely interact with their Matchers and by knowing that their Matchers didn't know their viewpoint relative to the array. Under these conditions, where the partner was restricted in interpreting or responding to their descriptions, speakers used the partner's viewpoint as a preferred organizing direction for encoding arrays. On the other hand, in our study, Directors in the Co-Presence condition knew at the time of study that the Matcher's viewpoint would be perceptually available during the description, that their own viewpoint would be perceptually available to the Matcher, and that they could interact freely. Under these conditions, the attributions that speakers made about their partner's ability to coordinate with them likely discouraged them from investing the cognitive resources to organize spatial relations in memory around their partner's viewpoint, and led them to simply encode that viewpoint and use it later flexibly and as needed.

In our view, attributions about the partner are more relevant to predicting perspective-taking behavior than *how* information about the partner's perspective actually comes about—whether through co-presence, explicit instructions, or schematic diagrams. When people assess that their partner's ability to coordinate is limited, they use the partner's viewpoint as an organizing direction, even if that viewpoint is indicated merely with an arrow around the speaker's to-be-learned spatial configuration (Shelton & McNamara, 2004). Similarly, depending on what they believe about their partner's ability to contribute, they adapt their descriptions (Schober, 1993, 2009) and the temporal and trajectory dynamics of their responses (Duran et al., 2011), even when the partner's viewpoint is depicted as an arrow in a schematic 2-D display (e.g., of a table with objects).

Altogether, our findings on Directors' memory performance are in line with the view that perspective-taking in dialogue is supported by ordinary cognitive processes acting on memory representations (e.g., Horton & Gerrig, 2002, 2005; Metzing & Brennan, 2003). According to this memory-based view of partner-specific adaptation, information about the partner can be represented in memory and affect perspective-taking when it is available and easily maintained, but not when it isn't available early enough (Kraljic & Brennan, 2005) or requires complex inferences (Gerrig et al., 2000). Here, we demonstrate that even the availability of such relevant, a priori information about the partner influences the spatial memory representations that speakers construct. When the partner's viewpoint is salient and available in advance, people encode it in spatial memory, but when it is unavailable they organize spatial information in memory according to egocentric experience.

Selecting the perspective of spatial descriptions: using in advance vs. perceptual information about the partner's viewpoint

Although people can encode partner-specific information in spatial memory, we have shown that when describing spatial information to a partner they don't solely rely on how their memory representations are organized. Advance knowledge of the partner's viewpoint does not determine on its own the preferred perspective of speakers' descriptions. Instead, speakers select the preferred perspective of their descriptions upon considering information from their shared perceptual experience during collaboration. Directors considered the degree of misalignment from their Matcher, available in the immediate perceptual environment to adapt their descriptions strategically, upon considering the cognitive demands on both partners. They did not necessarily use more partner-centered descriptions when they had known their partner's viewpoint in advance, and conversely they did not use more egocentric descriptions when information about the partner's viewpoint was unavailable at the time of study. Instead, they used partner-centered expressions more often at a small offset (at 90°), and egocentric expressions more often at the oblique 135°. Preference of the Directors' perspective was especially pronounced when pairs knew in advance that they would be offset by 135°, with Directors often explicitly agreeing with their Matcher to adopt their own perspective. Directors' overall perspective preferences were also consistent with this pattern: when Directors preferred overall their Matcher's perspective, they did so more frequently when misaligned by 90° with their Matcher, whereas when they preferred their own perspective, they did so more frequently when misaligned by 135°. Directors used mixed perspectives more frequently when they were counteraligned with their Matcher, suggesting that when sharing a canonical axis, people are more likely to alternate flexibly between descriptions from their own and their partner's perspective.

That speakers relied heavily on partner-specific information perceptually available during the interaction, while also considering whether this information was known in advance, is consistent with Li et al.'s (2011) finding that speakers use both perceptual information and their memories to select the perspective of their descriptions. In that study, speakers' perceptual viewpoint influenced the perspective they selected to verbally locate objects, even though they preserved their initial direction in memory (as corroborated by a set of JRDs, after verbally locating objects). Thus, both studies underscore that the way spatial information is encoded does not dictate how it will be subsequently described; perceptual information available during the description also influences the selection of a preferred perspective. Beyond Li et al. (2011), our own work underscores that in a social setting, such perceptual information shapes strategically the perspective of speakers' descriptions, according to partners' assessment of their relative cognitive demands.

Selecting the perspective of spatial descriptions: cognitive demands and joint agreements

We have shown that speakers use both perceptually available and in advance information to adapt their descriptions, presumably on the basis of attributions regarding the demands of perspective-taking on each partner. Since in our study the partners' respective viewpoints were perceptually available to one another during the description and they could interact freely, the burden of perspective-taking wasn't exclusively on Directors. When perspective-taking was difficult for Directors, they could alleviate some of their cognitive burden by describing spatial information from their own perspective, having their Matchers unpack the spatial mappings of these Director-centered descriptions.

Our study affords a novel contribution regarding when spatial perspective-taking is most demanding for speakers. It suggests that, at least when generating spatial descriptions, perspective-taking is more computationally demanding for speakers when they are misaligned by the oblique 135° offset than by the maximum offset of 180° from their partner. Directors were more likely to use egocentric expressions at 135° than at 90°, but no more likely to do so at 180°; in fact they were marginally less likely to use egocentric expressions at 180° than at 135°. Earlier studies have reported similarities in speakers' descriptions at different offsets: for instance, speakers describing arrays to misaligned partners used partner-centered expressions with comparable frequency, regardless of the degree of misalignment (Schober, 1993, 1995). However, our study suggests that these similarities may be limited to the orthogonal offsets used in these studies. Our findings are in line with McNamara's (2003) proposal that perspectives aligned with one's canonical axes are facilitated relative to oblique ones, and suggest that when describing spatial information, speakers do not simply mentally rotate the array to consider their partner's viewpoint (cf. Duran et al.'s, 2011, conclusions based on only orthogonal offsets between partners during the interpretation of spatial descriptions).

Notably, the demands of perspective-taking did not affect speakers' memory representations in the same way as their descriptions. For example, when speakers knew in advance that perspective-taking would be difficult for them, with the partner at 135°, they didn't simply ignore their partner's viewpoint but rather invested the cognitive effort to represent it in memory, even if they later opted for their own perspective in descriptions.

Together, these findings suggest that advance knowledge of the other's perspective enables partners to mutually recognize when the communicative situation would be more difficult for each partner and to adapt their strategies in ways maximizing the efficiency of communication. When perspective-taking was relatively easy for Directors they did what was easier for their Matcher, adopting the Matcher's perspective. On the other hand, when perspective-taking was difficult for Directors, partners mutually recognized this, with Matchers agreeing often explicitly on Directors using their own perspective—a strategy that was harder for them but easier for their partner. Partners flexibly shared responsibility for mutual understanding, consistent with findings that when partners recognize that one partner is likely to find the interaction difficult, the other will invest greater cognitive effort to ensure mutual understanding while minimizing their collective effort (e.g., Bortfeld & Brennan, 1997; Clark, 1996; Clark & Wilkes-Gibbs, 1986).

Elsewhere, we have shown that the partners' description choices were successful at minimizing their collective effort (Galati & Avraamides, 2012). Additional analyses of the dialogues of the present corpus indicated that pairs took fewer conversational turns (i.e., uninterrupted stretches of speech by a partner) to reconstruct the arrays when Directors knew in advance that they would be misaligned by 135°—where, as we show here, they had frequently described arrays from their own viewpoint—

relative to other offsets. In fact, the more egocentric expressions Directors used the fewest turns pairs needed to coordinate. Thus, insofar as conversational turns reflect the pairs' difficulty in monitoring and coordinating their behavior (e.g., Clark & Wilkes-Gibbs, 1986), their agreed upon description strategies when perspective-taking was difficult for Directors indeed facilitated their coordination.

In the present work, we have focused on global adjustments of speakers' behavior—on speakers' spatial representations and on the overall distribution of their descriptions' perspectives. This raises the question of whether the adjustments we observed in speakers' descriptions reflect purely early (or a priori) choices for the perspective they assessed would minimize collaborative effort, or whether they were also shaped adaptively by the partner's feedback. To address this question, in follow-up analyses, we examined whether global, long-lasting switches in the person-centered perspective of Directors' descriptions were prompted by the Matchers' local feedback. We did not find such evidence: long-lasting switches in the Directors' person-centered perspective were not prevalent (occurring in 9 of the 52 codable blocks, often when recapping the array configuration) and were often self-initiated (only four of these switches could be unambiguously attributed to the Matcher). Most of the time, Directors used a consistent person-centered perspective throughout their descriptions (in 33 blocks); otherwise, they either alternated back and forth between the Director and Matcher's perspectives or opted for a non-person-centered perspective.

The paucity of global perspective-switches prompted by Matchers, along with our findings on partners' initial agreement on a perspective, suggest that the Matchers' feedback is most impactful at the beginning of the interaction, when discussing the perspective the Director should adopt. This is not to say that after that initial agreement speakers don't respond adaptively to their partners' proposals. When Matchers' proposals adopted a different person-centered perspective, we observed that Directors often reused that perspective locally in response, but typically resumed descriptions from the perspective previously used. But most frequently, the Matchers' clarification questions and proposals were consistent with the person-centered perspective already in use, or were otherwise neutral (e.g., inquiries about the distance, shape, or bearing between objects). Using a perspective that is locally consistent with that used by the partner contributes to quickly establishing an effective description scheme with the minimum collaborative effort (Garrod & Anderson, 1987). Although under some circumstances switching perspectives can be effective for coordinating (Brennan & Clark, 1996; Tversky, Lee, & Mainwaring, 1999), partners in collaborative spatial tasks generally abide to a consistent spatial perspective upon establishing an explicit or implicit conceptual pact.

Conclusion

To summarize, perspective-taking is affected both by the extent to which adopting the partner's perspective is computationally demanding and the extent to which information about the partner's perspective is available in advance. When adopting perspectives aligned with their partner, people access their partner's viewpoint from episodic traces and relate it to pertinent representations of spatial information. Although people can encode the partner's known viewpoint in memory, they need pragmatic motivation to use it as a preferred organizing direction for spatial relations: if they assess that their partner's ability to contribute to the interaction is limited, they will use it as an organizing direction (Shelton & McNamara, 2004), whereas if they assess that their partner is unconstrained in contributing to the interaction, they won't do so. Critically, even though people incorporate partner-specific information in memory when it is available, they use this information opportunistically and strategically when collaborating in spatial tasks. They use this information, along with other information from their perceptual environment, to gauge the demands of perspective-taking on each partner and adapt accordingly their perspective choices when describing spatial relations. This assessment affects their overall preference for a given perspective, the distribution of perspectives in their expressions, and the extent to which they explicitly agree on such a preference with their partner. These findings underscore that simple but relevant cues about the partner (e.g., the partner's location in space and, by extension, the relative difficulty of reasoning from their perspective) can be used flexibly to affect behavior (Brennan & Hanna, 2009; Galati & Brennan, 2010). Determining that the partner's perspective is relatively easy to adopt, whether through advance information or perceptual evidence, leads to readily adopting it, whereas determining that it is computationally demanding (especially through advance information) leads to other choices that maximize the efficiency of communication.

Spatial perspective-taking, thus, does not simply depend on whether people know the degree to which their partner's perspective departs from their own, but instead depends on the attributions they make about their respective ability to contribute to mutual understanding. In this respect, spatial perspective-taking in communicative tasks is not unlike other kinds of non-spatial perspective-taking where conversational partners may have different conceptual perspectives or background knowledge. For both spatial and non-spatial perspective-taking, partners consider their respective demands in adopting the other's perspective in trying to minimize their collective effort; this influences how they represent partner-specific information and how they adapt their perspective choices.

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