Cognition 121 (2011) 22–40

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Listeners invest in an assumed other's perspective despite cognitive cost

Nicholas D. Duran *, Rick Dale, Roger J. Kreuz

Department of Psychology, University of Memphis, Memphis, TN 38152, United States

ARTICLE INFO

Article history:
Received 17 February 2011
Revised 3 June 2011
Accepted 13 June 2011
Available online 12 July 2011

Keywords:
Perspective-taking
Audience design
Visuospatial processing
Mental rotation
Mousetracking

ABSTRACT

We explored perspective-taking behavior in a visuospatial mental rotation task that requires listeners to adopt an egocentric or "other-centric" frame of reference. In the current task, objects could be interpreted relative to the point-of-view of the listener (egocentric) or of a simulated partner (other-centric). Across three studies, we evaluated participants' willingness to consider and act on partner-specific information, showing that a partner's perceived ability to contribute to collaborative mutual understanding modulated participants' perspective-taking behavior, either by increasing other-centric (Study 2) or egocentric (Study 3) responding. Moreover, we show that a large proportion of participants resolved referential ambiguity in terms of their partner's perspective, even when it was more cognitively difficult to do so (as tracked by online movement measures), and when the presence of a social partner had to be assumed (Studies 1 and 2). In addition, participants continued to consider their partner's perspective during trials where visual perspectives were shared. Our results show that participants will thoroughly invest in either an other-centric or egocentric mode of responding, and that perspective-taking strategies are not always dictated by minimizing processing demands, but by more potent (albeit subtle) factors in the social context.

1. Introduction

When two people discuss the world around them, they adapt their utterances to particular perspectives in order to be understood. Suppose you, the reader, wish to know where Al Green's world-famous Full Gospel Tabernacle church is. If the authors knew you were from Memphis, we could respond: "By Graceland." If you had a novice's perspective on Memphis, we might adorn the description with more detail, such as: "About 20 min south of downtown Memphis, off Highway 55, also near Graceland." (e.g., Fussell & Krauss, 1992; Isaacs & Clark, 1987). If our spatial perspectives differed in some way (e.g., we were chatting over the phone), I might give you directions by tailoring them to your spatial perspective, such as "On *your* left will be Graceland, then Al Green will be just..." (e.g., Mainwaring, Tversky, Ohgishi, & Schiano, 2003; Schober, 1993, 1995). These adaptive processes are sensitive to a variety of factors, and sometimes speakers mix strategies during an interaction (Tversky, Lee, & Mainwaring, 1999). Research conducted during the past couple of decades has revealed a diversity of constraints on how these speech acts are shaped by perspective (Schober, 1998, 2009). In general, when conditions are right, and cognitive constraints are satisfied, speakers seem to employ perspectives adaptively (see also Brown-Schmidt, 2009).

Relatively less is known, however, about how the addressee herself *adapts* to utterances inherently involving a spatial perspective. As noted above, speakers are neither always careful nor explicit with perspective choice, and listeners themselves can face moments of ambiguity. Above, when "On *your* left..." was used, it was assumed that the traveler is headed south from downtown Memphis. Yet conversational conditions do not always allow such ready assumptions. In the construction of directions relative to

* Corresponding author. Tel.: +1 909 569 2488; fax: +1 901 678 1336.
E-mail address: nduran@memphis.edu (N.D. Duran).

0010-0277/$ - see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.cognition.2011.06.009

some map, ''on the left'' is cognitively challenging and demands a referent object, as does ''near'' and ''far'' though they may be less challenging (Franklin & Tversky, 1990).

Earlier studies have suggested that perspective consistency facilitates comprehension (Black, Turner, & Bower, 1979; Tversky et al., 1999), and that different perspectives comprehended from text may allow varying levels of cognitive flexibility (Brunyé, Rapp, & Taylor, 2008). Many studies have explored the role of particular perspectives for memory encoding and access of maps or routes (McNamara, Sluzenski, & Rump, 2008; Mou, Liu, & McNamara, 2009), and such memories and related inferences are sensitive to factors such as familiarity with a terrain or environment, and aspects of a terrain like relative object salience (Taylor & Tversky, 1992, 1996). In addition, extensive work by Carlson and colleagues has shown that comprehenders might maintain activation across multiple perspective types before one is selected (Carlson, 1999; Carlson & Covey, 2005), a notion that Taylor and colleagues confirmed using online measures and event-related potentials (Taylor, Naylor, Faust, & Holcomb, 1999).

Though this extensive work on perspective comprehension and memory has done much to reveal underlying cognitive processes, we revisit a basic experimental design to ask the question: What spatial perspective do listeners adopt in the face of fundamental ambiguity? The work just reviewed almost always resolves the ambiguity *for* the listener in the task. For example, Taylor et al. (1999) ''force'' the participants to one or another perspective and observe the effects on processing (see also Black et al., 1979; Lee & Tversky, 2005; Samson, Apperly, Braithwaite, Andrews, & Bodley Scott, 2010; Tversky et al., 1999). The research on speakers' choices (e.g., Schober, 1993) is more open-ended – the tendency for speakers to adopt one or another framework in an open-ended way has been the focus of conversational spatial perspective-taking work.

To study the underlying cognitive processes involved in open-ended listener perspective-taking, we constructed a simple scenario modeled after Schober (1993) and Tversky and Hard (2009), but modified it to tap into the online comprehension of referential terms. This classic experimental design has been used frequently to study production (as reviewed above), but rarely have the spontaneous tendencies of listeners been studied (e.g., Fitneva & Song, 2009). In such cases, do listeners assume a consistent reference-frame over the course of an interaction? Previous research suggests that perspective switch costs are present during comprehension (Black et al., 1979), but in this research the listener was not given the opportunity to spontaneously choose a perspective under ambiguity.

In addition, will taking another person's spatial perspective (e.g., *their* left) always induce cognitive difficulty? As reviewed above, speakers sometimes *choose* the addressee's perspective, and here we test the same question with listeners. If taking another's perspective is cognitively challenging, will participants choose it as much as they would their own reference frame? With the cognitive expense of taking a perspective outside of one's own, our design permits open-ended exploration of the selection tendencies of comprehenders to take on their own or another's perspective. One could predict that cognitive load alone, without sufficient interactive constraints, favors taking the simplest perspective (often identified as one's own, from Levelt, 1989 to Epley, Keysar, Van Boven, & Gilovich, 2004, though there exists no consensus).

1.1. The social perspective-taking task

We modeled our task on the design of Schober (1993), who used a basic object-identification task to study perspective taking in speakers. Speakers saw two identical objects placed on a two-dimensional surface, and had to induce listeners to choose one of these objects. The speaker and listener could occupy different positions, under relative rotation of 90° or 180°, on this two-dimensional surface (designated on a simulated, drawn table on a piece of paper). Speakers thus had to formulate utterances using spatial descriptions that involved particular perspectives. For example, choosing her own perspective, a speaker could simply say: ''The object to my right.'' This perspective is often termed the egocentric perspective, because its frame of reference is the speaker herself. The speaker may also say ''The object to your left,'' thus taking the other person's perspective, which we will refer to as ''other-centric.'' Other possible descriptions can be used, such as ''object-centered'' (''Choose the one nearest the airplane picture''). In addition, speakers may simply produce ambiguous statements, like ''The one on the left'' when their positions are misaligned, and leave it to the listener to figure things out.

General findings using this design are that speakers take the addressee's perspective (i.e., they are other-centric) when communicating with a simulated partner, but will coordinate perspectives with actual partners when they are present (Schober, 1993), and will choose object-centered descriptions at times to avoid choosing an egocentric or other-centric perspective (Schober, 1995). In addition, they will adapt these utterances under different task conditions, such as directing their partners to the location versus asking about the location (Mainwaring et al., 2003). Others have found that taking the other-centric perspective may involve cognitive cost (Horton & Keysar, 1996). This simple task has thus revealed the adaptive tendencies of speakers in choosing spatial perspectives when formulating directions.

More recently, Tversky and Hard (2009) employed this sort of task in a simple experiment that showed that the mere implied presence of another person shaped the spatial perspective used by survey respondents. In a single-trial study, they presented participants with a picture of two objects and queried them about where one of the objects was located. The presence of a person in the picture, implying an ''other'' reference frame, induced usage of other-centric responses (e.g., ''on his left''). In a second study, they emphasized action in the instructions, and induced further other-centric descriptions. The authors concluded that the very presence of another person results in the use of ''external'' reference frames, and because this was done with only minimal cuing, there is a natural and spontaneous tendency to embody the spatial perspectives of another's actions or potential actions.

One implication from Tversky and Hard (2009), and from the results of Schober (1993), is that participants are willing, even with very minimal and non-interactive cues, to take the perspective of another, despite the fact that some have suggested that this perspective is not the default and is cognitively costly (Epley et al., 2004; Horton & Keysar, 1996). However, in these previous studies, no online measure of cognitive processing was extracted to confirm either of these findings in the context of the perspective-taking task. To do so here, we created a scenario that required participants to select and present objects to a simulated partner. The generated actions were analyzed for overall time of execution, as well as for more nuanced and graded signatures of difficulty that would be problematic, if not impossible, to capture with simple button presses.

Another unaddressed issue is that neither Schober (1993), nor Tversky and Hard (2009), explored the tendencies of the listener, who may be equally willing to invest in the other-centric perspective during occasionally ambiguous exchanges. In the following three studies, our task offers answers to these basic questions. First, we show that even with a cognitively costly other-centric perspective, requiring measurable mental rotation to take on this perspective, comprehenders of directions will invest other-centrically. We show that this happens even during trials when there is a shared perspective – when the egocentric perspective is all that is needed to solve the task – participants still pay the cognitive cost to "transform" the visual array to accommodate an assumed partner. In a second and third study, we show that comprehenders' perspective-taking behavior is influenced by the pragmatic constraints in the communicative environment. Participants may seek to optimize mutual understanding with their partner, and depending on an assessment about the partner's ability to do the same, other-centric interpretations can increase or decrease dramatically. Like Tversky and Hard (2009), we employed a very simple task, but embedded it in a sequence of trials and captured online cognitive measures. And like these authors, we show that there is spontaneous, strategic investment in other-centrism despite its difficulty.

2. Study 1: Listener's perspective choice in an ambiguous spatial layout

We simulate a simple interaction where a person, standing at a table, asks another person to hand him a folder from a set of two folders laid out on the tabletop, as in "Give me the folder on the left." Such a request would be straightforward if both speaker and addressee were standing side-by-side with a shared perspective of the table. However, if the speaker were to walk around the table, now facing the addressee from the opposite side, the same request presents a coordination problem for the addressee. Should the interpretation be grounded in one's own frame of reference, or that of the other? And if addressees are unable to ask for further clarification (for example, the speaker becomes distracted or momentarily leaves the room), what are the constraints in the communicative context that might influence their decision?

The above scenario was implemented in a computer-based environment where requests for a folder were made by a virtual speaker, whose location around a simulated table changed from trial to trial. For some of these trials the requests were ambiguous, allowing participants to respond either ego- or other-centrically. To make a decision on how to respond, we hypothesize that participants are likely considering many factors, with arguably the most important being the characteristics of the speaker and his intended meaning.

For this task, there are two speaker-related influences that have particular relevance. First, although the virtual speaker sounds natural from turn-to-turn, the speaker is nevertheless delivering pre-recorded speech. As a result, participants could react by viewing this simulated partner as a nonentity that cannot possibly possess a unique perspective, thus making the egocentric response the only viable option. The recording could also fail to activate other-centric inclinations that, with a real partner, would normally lead to other-centric responding. Second, given the lack of explicit feedback, there is no way of knowing the speaker's intent, thus there is little risk in choosing a "wrong" response. Therefore, it is reasonable to suspect that the interpretation that requires the least amount of cognitive effort, namely, the egocentric response, would be preferred.

Yet, the limitations of the simulated partner could also be the very basis for taking the partner's perspective. Such behavior would occur if participants were approaching the interaction as a collaboration for establishing mutual understanding. According to the work of Clark and colleagues, conversational partners optimize understanding by attempting to minimize the effort for both themselves and their partner (Clark, 1996; Clark & Krych, 2004; Clark & Wilkes-Gibbs, 1986). Moreover, if it appears that one of the partners is failing to understand (Horton & Gerrig, 2002, 2005), or is likely to find the interaction difficult (Bortfeld & Brennan, 1997; Brennan, 1990), the other will expend greater cognitive effort to ensure mutual understanding. These assessments of the partner are rapidly made, and can be influenced by knowledge of the other's needs, characteristics, or limitations at the start of the interaction, as in adjustments based on a partner's age or a known language disorder (Newman-Norlund et al., 2009; Perkins & Milroy, 1997). Here, not only must an assessment be made in the service of comprehension, but it must also be extended to a partner who is incapable of collaboration. If the participant accepts the burden of ensuring mutual understanding, and the limitations of the recorded speaker are deemed sufficient, we would expect higher rates of other-centric responding.

Finally, a central claim emphasized earlier is that the other-centric response requires greater cognitive effort. To be clear, we consider cognitive effort to be the amount of mental work devoted to linguistic comprehension. But unlike the many language studies where effort is confined to retrieving words or parsing sentences, here effort is extended to a larger pragmatic and visuospatial context. To interpret a verbal request other-centrically, not only must participants consider the abilities of their partner, but also their partner's location in space. As such, cognitive effort can be operationalized in the same ways as those used in well-established research on visuospatial perspective transformations (see Zacks and Michelon (2005) for a review).

In this previous research, it has been shown that it takes longer to describe objects from locations that are offset from one's own location (i.e., egocentric). Moreover, the greater the deviation from the egocentric perspective, the greater the time it takes to respond. This effect also holds when describing objects from another person's perspective (Schober, 1993, 1995), regardless of whether the person is real or simulated (Amorim, 2003; Schober, 1993) or perspective choice is spontaneous or forced (Samson et al., 2010). Our scenario allows participants to freely adopt the perspective of a simulated partner, and to do so at varying locations of difficulty. This difficulty is implemented by offsetting the partner's location by 90°, 180°, and 270° relative to the participant. The further participants must mentally rotate from their own egocentric perspective to "view" the table from their partner's egocentric perspective, the greater the cognitive effort invested.

2.1. Participants

We recruited 89 participants using Amazon's Mechanical Turk.[1] Mechanical Turk is an online service that allows users to post tasks that require human expertise, like rating the usability of websites or compiling lists of business addresses. Tens of thousands of potential "workers" complete tasks on their computers and receive a nominal payment in return. Recently, cognitive psychologists and other scientists have begun exploring the potential of Mechanical Turk for behavioral research (e.g., Dale & Duran, in press; Dale, Duran, & Morehead, submitted for publication; Frank & Gibson, 2011). Respondents are found to exhibit consistently high inter-subject reliability (Kittur, Chi, & Suh, 2008; Snow, O'Connor, Jurafsky, & Ng, 2008; Sorokin & Forsyth, 2008), and maintain excellent reliability and significant correlations with laboratory-collected data (Munro et al., 2010). Moreover, because participants are not necessarily aware that they are being tested, nor is an experimenter present, demand characteristics are reduced.

Participants in the current study (i.e., "task") were paid 40 cents for contributing responses over a 7–12 min period. To identify unique responders, the IP address of each participant's computer was recorded and associated with their data. If multiple sets of data had the same IP address, we discarded these sets because the same participants may have completed the task more than once. If IP addresses did not originate from the United States, these data too were discarded. Once we identified unique responders, the IP addresses were deleted from all files. It should also be noted that prior to committing to the study, participants were aware of the general purpose of the study and that they were free to terminate at any time (although payment would be forfeited per Amazon Mechanical Turk rules).

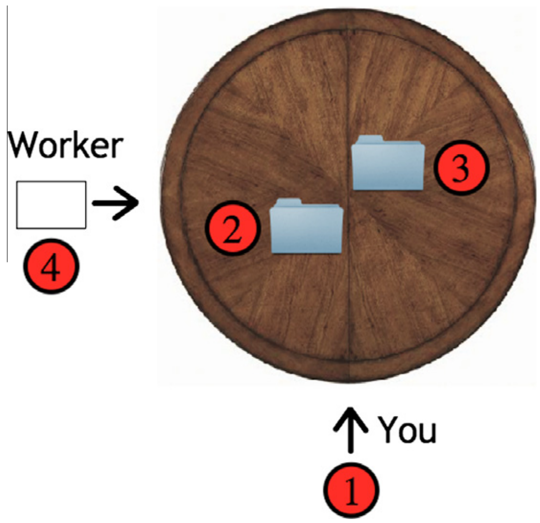

Fig. 1. The experimental interface for capturing egocentric or other-centric behavior in a single computerized task. *Note*: The numeric labels are for explanatory purposes only and were not seen by participants.

2.2. Method

The experiment was implemented in Adobe Flash and is accessible from an Internet web browser.[2] Upon navigating to the correct webpage, participants read brief instructions informing them that they would have to respond to simple requests from a simulated partner.[3] The participants then proceeded by clicking a button with their computer mouse to reveal an image of an empty tabletop that was centered within a 330-by-330-pixel region on their computer screen. After a brief pause (around 500 ms), a recording of their male partner's voice was automatically played. The partner directed the participant to select one of two folders that would appear on the tabletop. Each folder was 67-by-50-pixels in size. The partner's directions always began with the phrase "Give me the folder that is..." and was completed with, "on the right," "on the left," "in the back," or "in the front." After hearing these directions, participants clicked on a "GO" label at the bottom of the screen (centered 65-pixels below the tabletop image). At this point, the orientation of the folders and the location of the partner and participant became visible. The folders were arranged in one of four possible orientations: top-right diagonally (Fig. 1, Position 2 and 3), top-left diagonally, vertically, or horizontally, whereas the participant's location was always located at a ground position of 0° (Fig. 1, Position 1). The participant's task was to select a folder and drag it to the

[1] www.mturk.com.

[2] A version of the experiment can be accessed at: cognactive.org/perspectiveTask.

[3] This partner was labeled as either an "Employer" or "Employee" in Studies 1 and 2. These designated labels were used to test a separate research question on social identity. No clear and consistent patterns in responses were found between these labels. The analyses here are based on the combined datasets.

partner's position around the table. The partner could appear in any of the four positions of 0°, 90°, 180°, or 270° (Fig. 1, Position 4).

The partner's verbal directions were strategically paired with particular folder/partner combinations to create 20 shared-perspective and 20 critical trials. It is during the critical trials that a participant's current spatial perspective taking is revealed. For example, based on the layout of Fig. 1, if the participant hears, "Give me the folder on the left," and selects the folder at Position 2, they are acting egocentrically ("folder on *my* left"). But if the folder at Position 3 is selected, the participant is now acting "other-centrically" ("folder on *your* left"). Given the same layout, a shared-perspective trial would occur if the participant now hears, "Give me the folder in the front." Regardless of whether the participant takes an egocentric or other-centric perspective, the folder at Position 2 is aligned with both perspectives and should always be selected. These trials serve as a type of control.

As participants moved toward a folder, we were rapidly sampling the *x*, *y* coordinates of their mouse cursor (similar to Brennan, 1990). These coordinate positions were recorded every 25 ms (a sampling rate of 40 Hz) from the moment the "GO" region was clicked to the initial selection of a folder. The "GO" region is a point of calibration that ensures all responses begin at the same location. The subsequent temporal and trajectory analyses are based on these movements.

In presenting the stimuli to participants, we randomly shuffled shared-perspective and critical trials, ensuring that no more than three trials of the same type ever occurred in a sequence. In each list, all possible combinations of folder orientation and partner location were seen at least twice – except for horizontal and vertical orientations when participants were located at 90° or 270°. At these combinations, the directions are no longer ambiguous and are likely to bias perspective choice. For example, imagine the scenario where the speaker is offset by 90° and the folders are laid out vertically. If the speaker asks for the folder on the right, the participant is forced to consider the speaker's perspective because "right" is interpretable only from where the speaker is located. Additional constraints made it impossible for the speaker in critical trials (nonshared-perspective) to appear at the 0 degree location (shared-perspective), and for the speaker in shared trials to appear at the 180 degree location (nonshared-perspective). In the end, the 20 critical trials consisted of 4 trials each at the 90 and 270 degree position, and 12 at the 180 degree position. The same was true for the 20 shared-perspective trials, except now with 12 trials at the 0 degree position. Finally, for trials at the 90 and 270 degree positions, and separately at the 0 and 180 degree positions, there were an equal number of folders oriented top-right and top-left diagonally, and from each direction type. Trials at the 0 and 180 degree position also included the horizontal and vertical orientations.

2.3. Results

To ensure that participants were committed to the task, we identified suspicious behavior like random guessing and excessive delays. Guessing is evident in the shared-perspective trials where a response to the partner's directions should always converge on a single folder. If this target folder was *not* selected, then the response was flagged as an error. Furthermore, if a trial lasted for more than ten seconds, it too was flagged. Participants who made two or more errors were excluded. A total of eight participants, or 8.98% overall, were removed. In addition, 101 trials, or 3.16% overall, were removed because the response time to select a folder exceeded three standard deviations above the mean (i.e., greater than 3986 ms).

2.3.1. Patterns of egocentric and other-centric responders

Based on the consistency of responses across critical trials, participants were classified as egocentric, other-centric, or mixed responders. To identify category membership, we computed proportions of egocentric and other-centric trials for each participant. If proportion scores exceeded 0.70 for one of the two response categories, then the participant was considered to be a member of that category. Participants scoring below 0.70 were labeled as mixed responders. There were only 8 (or 9.76%) mixed responders. Participants tended to be on the extreme ends of a bimodal distribution, with 31 participants (38.80%) classified as egocentric and 43 participants (52.44%) as other-centric. However, this difference was not statistically significant, $X^2(1) = 1.95$, $p = 0.16$.

2.3.2. Greater processing costs in taking another's perspective

In this analysis, we evaluate whether other-centric responders are mentally rotating to their partner's visual perspective. To do so requires the participants to rotate from their own spatial frame of reference, located at ground position 0°, to the partner's perspective that is located at position 90°, 180°, or 270°. This rotation should be increasingly difficult the further the rotation is from the personal frame of reference (Michelon & Zacks, 2006; Miller & Johnson-Laird, 1976; Presson & Montello, 1994; Shepard & Metzler, 1971; Zacks, Vettel, & Michelon, 2003). Thus, when the partner is rotated 180° (directly across from the participant) there will be greater processing difficulty than when the partner is rotated 90° (at a ground position of 90° or 270°). Because this behavior is expected to occur just with other-centric responders, processing times at each of the ground positions should also be much higher when compared to egocentric responders.

We used a linear mixed-effects model[4] to evaluate response time differences across degree of rotation (within-subjects factor; three levels: 0° vs. 90° vs. 180°) and responder type (between-subjects factor; two levels: consistent egocentric vs. consistent other-centric). It is important to note that the rotated position at 90° also includes trials at 270° because both positions require equivalent degrees of rotation. To simultaneously account for random variance due to participants and items, "participant" was added as a random effect, as well as folder orientation (e.g., horizontal, diagonal, and vertical), and verbal directions

[4] Models were built using the PASW (SPSS) MIXED procedure, with denominator degrees of freedom estimated using Satterthwaite's approximation (default).

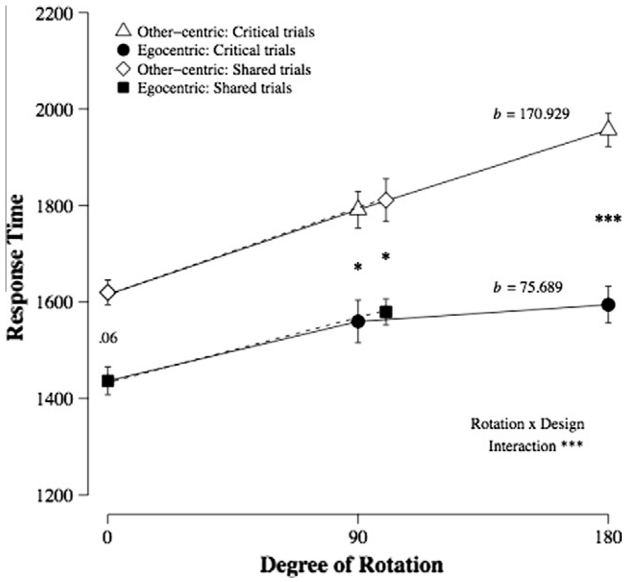

Fig. 2. The critical trial response times and standard errors of egocentric and other-centric responders at 90 and 180 degrees of partner rotation, and shared-perspective response times at 0 degrees of rotation. For each increase in rotation, other-centric responders take much longer than egocentric responders. Other-centric responders are also slower than egocentric responders at each degree of rotation (Section 2.3.2), including shared-perspective response times at 0 degrees of rotation and 90 degrees of rotation (Section 2.3.4). Furthermore, other-centric critical and shared-perspective response times at 90 degrees of rotation are nearly identical (Section 2.3.4). *Note*: Statistical significance is coded as: $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

("e.g., "right," "left," "front," and "back"). As an additional precaution that would control for practice effects, models with and without trial number were compared using a log-likelihood ratio test as recommended by Baayen (2008) and Quene and van den Bergh (2008). The addition of trial number resulted in a model with a better overall fit, and was therefore included as another random effect.[5]

The overall model revealed a statistically significant main effect for degree of rotation, $F(2, 1424.03) = 48.62$, $p < .001$, a significant main effect for responder type $F(1, 66.75) = 7.72$, $p = .007$, and a significant interaction between the two factors, $F(2, 2066.31) = 2066.31$, $p = .001$. Given the significant interaction, follow-up simple main effects were conducted across degree of rotation for egocentric and other-centric responders. For other-centric responders, there was an overall significant effect, $F(2, 1562.86) = 54.02$, $p < .001$, resulting from increased cognitive processing across degree of rotation (see Fig. 2). Planned comparisons show significant difference between 0° and 90° (mean difference = 172 ms[6]), $p < .01$, Cohen's $d = .17$; and between 90° and 180° (mean difference = 164.66 ms), $p < .01$, $d = .27$. For egocentric responders, although no significant increase was expected, these participants also appear to consider some aspect of the partner's changing location, $F(1, 1792.42) = 9.12$, $p < .001$, but only when location shifted from 0° to 90° (mean difference = 123 ms), $p < .01$, Cohen's $d = .05$. Yet, it is clear that other-centric responders are engaged in greater cognitive work, as the average linear increase of response time for other-centric responders was much higher than that of egocentric responders. To demonstrate this overall increase, an additional mixed-effects model was computed with response time regressed on degree of rotation, now coded as a continuous factor (e.g., "1", "2", and "3"). The slope of the linear regression line for other-centric responders, $b = 170.93$, is much steeper than that of egocentric responders, $b = 75.67$, $F(2, 1637.83) = 65.69$, $p < .001$.

The other-centric response times at each of the three ground positions (0°, 90°, and 180°) were also significantly higher than those of egocentric responders. A series of analyses based on the overall model confirmed that at 0 degrees of rotation, other-centric responders were 183 ms slower, $F(1, 78.36) = 3.57$, $p = .06$ (marginal), $d = 0.37$; at 90 degrees of rotation, other-centric responders were 232 ms slower, $F(1, 92.07) = 5.29$, $p = .02$, $d = 0.40$; and at 180 degrees of rotation, other-centric responders were 361 ms slower, $F(1, 79.06) = 13.81$, $p < .001$, $d = 0.50$. Taken together with the previous results, even though egocentric responders appear to be affected at some level by the locational changes of the recorded speaker, other-centric responders are taking on the additional processing costs of mental rotation.

2.3.3. Greater processing complexity and competition for other-centric responders

As participants use their mouse cursor to select a folder, fine-grained changes in the decision movement

[5] These random effect variables are included in all subsequent mixed-effects analyses. The specific model used here was chosen to give a conservative unbiased evaluation of the dependent variables, following established parameter specification techniques (Baayen, 2008; Baayen, Davidson, & Bates, 2008; Quene & van den Bergh, 2008).

[6] All reported and plotted means are the estimated marginal means that have been adjusted by linear mixed-effects models to remove random variance due to participant, item, and practice effects. The estimated marginal means are those used by the model to derive inferential statistics, and represent a better, unbiased account of outcome response patterns.

Table 1
Study 1: Means and standard errors for directional shifts, maximum deviation, and acceleration components at 0, 90, and 180 degrees of rotation.

Rotation	Directional shifts		Maximum deviation		Acceleration components	
	Ego	Other	Ego	Other	Ego	Other
0	1.23 (.06)	1.47 (.05)	12.16 (1.58)	18.83 (2.27)	8.78 (.23)	10.29 (.23)
90	1.32 (.07)	1.65 (.07)	11.12 (1.46)	25.64 (2.16)	9.79 (.34)	11.22 (.30)
180	1.36 (.07)	2.07 (.07)	8.45 (.77)	23.15 (1.54)	9.70 (.29)	12.17 (.29)

are captured. These changes reflect processing complexity and competition as a decision is made. Here, we consider three trajectory measures of complexity and competition: *directional shifts in motion*, *maximum deviation*, and *acceleration components*. Directional shifts occur when the mouse cursor switches direction along the x- or y-axis, depending on the orientation of the folders. For example, as a participant moves from the bottom of the screen to a folder, they might change their mind and move towards the other folder. This change will be reflected in a flip of direction along the axis in which folders are arranged (x-axis for diagonal and horizontal; y-axis for vertical). We can also measure the strength of the initial bias that brought about the directional flip. Because the visually co-present folders in the horizontal and diagonal configurations are laid out side-by-side along the x-axis, and the initial location of the cursor at the bottom of the screen is set equidistantly between the two folders, (x, y = 0, 0), we can measure the maximum deviation away from 0 that the trajectory is "pulled" (also see Spivey & Dale, 2006). Here, "pull" is toward the competitor folder, as would be the case for other-centric responders that move towards the "egocentric" folder while making a final selection. Presumably, the further responders travel towards the egocentric folder en route to their final selection, the stronger the bias to respond egocentrically (or other-centrically in the case of egocentric responders).

Alternatively, uncertainty and competition in selecting a folder can occur without directional change along an axis. In this scenario, a participant makes an initial confident response towards one folder, but slows down, and then speeds up, as they deliberate about their final response. The acceleration component measures the number of such response hesitancies (Dale & Duran, in press). All three measures supplement reaction time by providing further evidence of the increased cognitive effort associated with being other-centric.

2.3.3.1. Directional shifts. As with the reaction time data, a mixed-effects analysis was conducted with degree of rotation and responder type as fixed effects. Both main effects were statistically significant (both at the $p = .001$ level), as was the interaction term $F(1, 1938.59) = 8.55$, $p < .001$. Based on the means reported in Table 1, the directional shifts for other-centric responders appear to increase with degrees of rotation. This pattern was validated with a simple effects analysis, $F(2, 1418.71) = 31.97$, $p < .001$, with significant increases from 0° to 90° (mean difference = 0.18 shifts), $p = .04$, $d = .15$ and from 90° to 180° (mean difference = 0.42 shifts), $p < .001$, $d = .32$. For egocentric responders, there were no statistically significant increases. Further comparisons also show that the other-centric responders had more shifts than egocentric responders at each of the three ground positions: 0° (mean difference = 0.24 shifts), $F(1, 103.19) = 3.03$, $p = .08$ (marginal), $d = .27$; 90° (mean difference = 0.33 shifts), $F(1154.83) = 4.83$, $p = .03$, Cohen's $d = .36$; and 180° (mean difference = 0.71 shifts), $F(1, 106.38) = 26.43$, $p < .001$, Cohen's $d = .49$.

2.3.3.2. Maximum deviation. The main effect for responder type was significant, $p < .001$, as well as a significant interaction between responder type and degree of rotation, $F(2, 1693.31) = 3.41$, $p = .03$. For other-centric responders, there was greater movement toward a competitor folder between 0 and 90 degrees of rotation (mean difference = 6.81 pixels), $p = .004$, $d = .17$. For egocentric responders, there were no equivalent movements. The comparisons at each of the ground positions also show that other-centric responders deviate more toward the competitor folder at 0° (mean difference = 6.67 pixels), $F(1, 153.06) = 4.31$, $p = .04$, Cohen's $d = .17$; at 90° (mean difference = 14.52 pixels), $F(1, 218.63) = 16.89$, $p < .001$, $d = .48$; and at 180° (mean difference = 14.71 pixels), $F(1, 83.19) = 10.83$, $p < .001$, $d = .62$.

2.3.3.3. Acceleration components. Both main effects were statistically significant (degree of rotation, $p < .001$; responder type, $p = .01$), as was the interaction term, $F(2, 1937.42) = 3.11$, $p = .04$. Follow-up analysis on the interaction shows an increase for other-centric responders across each degree of rotation, $F(2, 1740.46) = 4.89$, $p = .008$; with the planned comparison between 0° and 90° being significant (mean difference = 0.93 components), $p = .004$, $d = .10$, and the comparison between 90° and 180° also significant (mean difference = .95 components), $p = .004$, Cohen's $d = .18$. We also found a significant increase of acceleration components for egocentric responders, $F(2, 1569.07) = 21.59$, $p < .001$, but only for the planned comparison between 0° and 90°, mean difference = 1.00 components, $p = .01$, $d = .12$. Finally, other-centric responders exhibited more acceleration components at each of the three ground positions: 0° (mean difference = 1.51 components), $F(1, 82.09) = 4.06$, $p = .05$, $d = .37$; 90° (mean difference = 1.43 components), $F(1, 100.54) = 3.32$, $p = .07$ (marginal), $d = .32$; and 180° (mean difference = 2.47 components), $F(1, 83.19) = 10.83$, $p = .001$, $d = .43$.

Overall, the trajectory measurements provide a more detailed evaluation of the decision dynamics that occur during the time required to initiate and finalize a response movement. For each measure, the decision to be other-centric is marked by greater instability, and that the activation of the competitor response, e.g., the egocentric option, is strongest for other-centric responders. Moreover, the processing difficulty associated with mentally rotating to a partner's visual perspective is amplified the further respondents must travel in the rotation. This latter finding generally holds for other-centric response behavior, with the exception of maximum deviation from ground positions 90° to 180° (although the increase from 0° to 180° was statistically significant, $p = .01$). And like the overall response time analysis, there was some evidence that the partner's changing location added some complexity to egocentric responding, but only with acceleration components between 0 and 90 degrees of rotation. There were no equivalent effects with directional shifts and maximum deviation.

2.3.4. Perspective-taking during shared trials

In the previous response time analysis (Section 2.3.2 above), the 0-degree rotated position was included as a baseline in which participant and their partner shared the same view of the table (and consequently, visual perspectives were aligned). At 0° there is no need to mentally rotate; thus, other-centric response times may be similar to that of egocentric responders. However, as evident by the 183 ms difference, other-centric responders are somewhat slower. This result suggests other-centric responders are continuing to consider their partner's perspective, even when it is unnecessary to do so. As further evidence, we compared the shared-perspective trials of egocentric and other-centric responses at 90 degrees of rotation. If other-centric responders are mentally rotating and egocentric responders are not, then other-centric responders will again be slower. Indeed, this result was confirmed, (mean difference = 207 ms); $F(1, 90.44) = 5.24$, $p = .02$, $d = .29$ (see Fig. 2). Finally, we assessed just other-centric responses during shared-perspective and critical trials at 90 degrees of rotation. Unlike the critical trials, the shared-perspective trials present a situation where the perspectives of participant and partner converge on the same folder. These trials may be easier because there is no conflict between perspectives ("your right" or "my right"), thus there is no need for other-centric participants to inhibit activation from their own perspective ("my right"). However, the response times for critical and shared-perspective trials were nearly identical, (shared: $M = 1756$ ms, SE = 44 ms; critical: $M = 1792$ ms, SE = 38 ms); $p > .10$, suggesting that other-centric responders are continuing to mentally rotate, even when the visual context does not place any demands on them to do so.

2.4. Brief discussion

Given an ambiguous spatial perspective task, participants exhibit an almost equivalent preference in taking an egocentric or other-centric perspective. This commitment to any one perspective is a consistent mode of responding that persists over an extended interaction with an assumed social partner. Furthermore, we show that other-centric responders are spontaneously choosing what is a more cognitively challenging behavior. To take another's perspective, responders are mentally rotating to the spatial location of their partner. In doing so, they are quite literally taking on the visual perspective of their partner. Not only does this process take longer the greater the required rotation, but it is also marked by signatures of processing complexity. Even so, more than half of the participants in this study chose to accommodate the perspective of their partner – a partner that participants know to be a mere simulation.

3. Study 2: Perspective-taking modulated by attributional cues

To respond other-centrically, participants appear to be engaging in a pattern of behavior that optimizes the understanding of the other. Although the "other" in the current context has no need or ability to understand, participants still adhere to principles of collaboration, an apparent default for social interaction. Thus, when a partner is unable to contribute equally to the collaboration, the more adept partner expends greater effort to do what the other cannot (Branigan, Pickering, Pearson, & McLean, 2010; Brennan, 1990). Of course, the question still remains: why then do a large proportion of participants still act egocentrically? One possibility is that the constraints in Study 1 are simply insufficient. These constraints lack the force to trigger attributions that are necessary for other-centric responding (Clark & Schaefer, 1989; Clark & Wilkes-Gibbs, 1986; Wilkes-Gibbs & Clark, 1992). Such ineffectiveness might be due to responders who have a high criterion for establishing a collaboration or noticing when a collaboration becomes unbalanced. Either way, by introducing a potentially more relevant constraint, or *attributional cue*, the rate of other-centric responding should dramatically increase. However, if responders are ignoring the other as irrelevant, and acting solely to minimize their own cognitive effort, then the additional cue should have little effect on the overall pattern of perspective-taking behavior.

In Study 2, we chose an additional attributional cue that would be relevant only if participants were treating the simulated speaker as a potential collaborator. As such, we simply informed participants that their partner does not know where they are seated at the table. Now, when the participant hears a verbal direction like, "Give me the folder on the right," the interpretation must take into account that the partner's knowledge state precludes the possibility of "on the right" meaning the participant's "right". The partner can only give directions from her own perspective; thus, the participant should respond other-centrically. In addition, using the same cognitive measures, we consider whether this additional cue to be other-centric makes an other-centric response easier, or continues to be the more difficult option.

3.1. Participants

We recruited 96 participants using Amazon's Mechanical Turk. Each was compensated with a small monetary payment (40 cents). The participants' IP addresses were also different from those in Study 1.

3.2. Method

The only difference from Study 1 is a slight change in the initial instructions. We now include the statement: "Your partner DOES NOT know where you are seated." All other aspects of the experiment were identical.

3.3. Results

We removed 15 participants, or 15.62% overall, who appeared to be randomly guessing on shared-perspective trials, or took an excessive amount of time to answer (greater than 10 s). We also removed 61 trials, or 2.62% overall, that were three standard deviations above the response time mean for selecting an initial folder (i.e., 3634 ms).

3.3.1. Patterns of egocentric and other-centric responders

If participants are considering what their partner knows, it is expected that the introduction of a more perspicuous attributional cue will shift the distribution of consistent responders toward other-centric. Indeed, there was evidence of this effect. Based on the proportion of response type over critical trials, 18 (22%) participants consistently responded egocentrically on more than 70% of the trials, and 60 (74%) participants consistently responded other-centrically. This difference between other-centric and egocentric responders was significant, $X^2(1) = 22.62$, $p < .001$. Only 3 (3.7%) participants were mixed responders (see Fig. 3). Furthermore, not only was there a difference of other-centric and egocentric responding within Study 2, but when compared against Study 1, other-centric responders increased by 22%, $X^2(1) = 6.82$, $p < .01$, whereas egocentric responders decreased by 16%, $X^2(1) = 4.21$, $p = .04$.

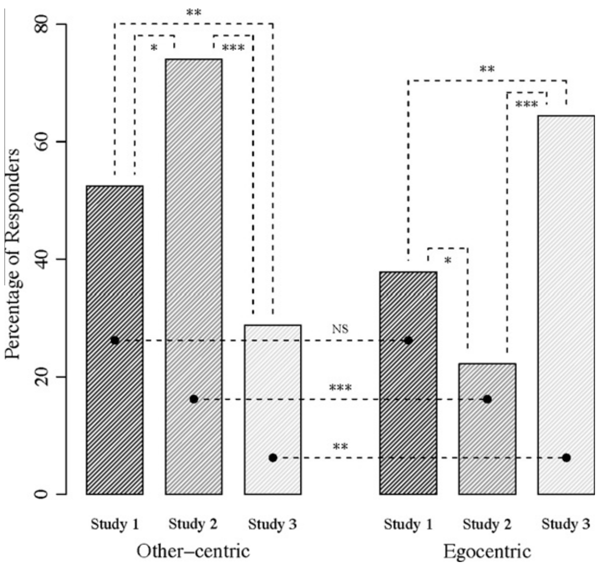

Fig. 3. Distribution of egocentric and other-centric responders across the three studies. For Study 2, there are a greater number of other-centric responders and fewer egocentric responders when compared to Study 1. For Study 3, this pattern is reversed, with a greater number of egocentric responders and fewer other-centric responders when compared to Study 2 and Study 1.

3.3.2. Greater processing costs in taking another's perspective

A linear mixed-effects model wth response time as the dependent variable revealed a significant interaction between rotation and responder type, $F(2, 2193.62) = 7.19$, $p = .001$. Starting with a closer examination of other-centric responders, the linear increase across 0°, 90°, and 180° was statistically significant, $F(2, 1061.13) = 44.19$, $p < .001$. Planned comparisons show a marginally significant increase between 0° and 90° (mean difference = 59 ms), $p = .07$, $d = .10$; and between 90° and 180° (mean difference = 202 ms), $p < .001$, $d = .32$ (see Fig. 4). For egocentric responders, there was an overall marginally significant increase, $F(2, 2019.48) = 2.42$, $p = .09$, but was confined to the increase from 0° to 90°, mean difference = 120 ms, $p = .04$, $d = .13$. To evaluate whether this egocentric increase was equivalent to the other-centric increase, we regressed reaction time on degree of rotation, with degree of rotation coded as a continuous variable. As expected, the fitted regression lines were significantly different, with other-centric rising on average 132 ms and egocentric only rising 47 ms, $F(2, 1904.15) = 44.70$, $p < .001$.

Interestingly, in the between-subjects analysis at each degree of rotation, other-centric responders took much longer to respond than egocentric responders at two of the three ground positions (Fig. 4). Follow-up comparisons show statistically significant differences at 0° (mean difference = 203 ms), $F(1, 88.01) = 2.91$, $p = .09$ (marginal), $d = .28$; and at 180° of rotation (mean difference = 380 ms), $F(1, 90.35) = 9.99$, $p = .002$, $d = .46$.

3.3.3. Processing complexity and competition for other-centric responders

Separate mixed-effects models were built with each of the three trajectory measures as dependent variables. The measures, and their descriptives, are displayed in Table 2.

3.3.3.1. Directional shifts. The interation for the overall model was statistically significant, $F(2, 2094.61) = 3.60$, $p = .03$. With this measure, other-centric responders had more shifts across rotated positions, $F(2, 2092.19) = 19.85$, $p < .001$, particularly between 0 and 90 degrees rotation, mean difference = .341 shifts, $p < .001$, $d = 28$. And, as in the previous analysis, other-centric responders had more shifts than egocentric responders at each ground position: at 0° (mean difference = .494 shifts), $F(1, 108.16) = 8.81$, $p = .004$, $d = .42$; at 90° (mean difference = .449 shifts), $F(1, 150.56) = 6.13$, $p = .01$, $d = .36$; and at 180° (mean difference = .796 shifts), $F(1, 115.24) = 22.15$, $p < .001$, $d = .58$.

3.3.3.2. Maximum deviation. Only a statistically significant main effect for degree of rotation was found for this study, $F(2, 1827.93) = 4.19$, $p = .02$, $d = .25$, showing a significant increase of 6.73 deviations from 0 to 90 degrees of rotation.

3.3.3.3. Acceleration components. A statistically significant main effect for degree of rotation, $F(2, 2092.22) = 2.27$,

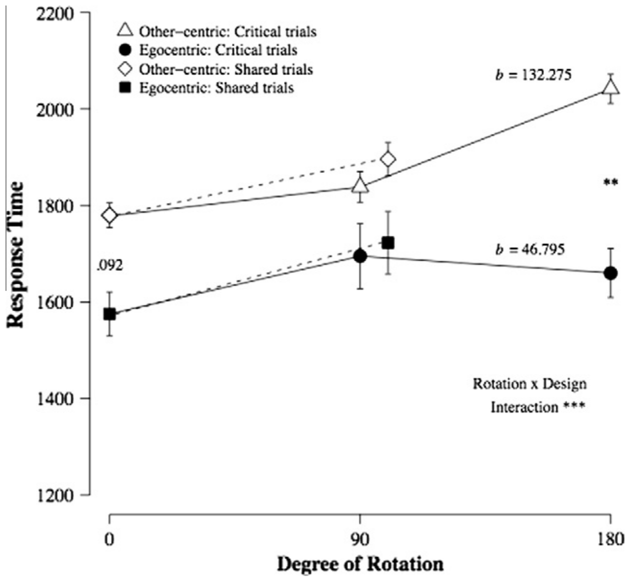

Fig. 4. The critical response times and standard errors of egocentric and other-centric responders at 90 and 180 degrees of partner rotation, and shared-perspective response times at 0 degrees of rotation. Between 0–90°, and 90–180°, other-centric responders take more time, whereas egocentric responders increase from 0° to 90° (Section 3.3.2). However, other-centric responders are overall slower than egocentric responders (Section 3.3.2), including shared-perspective response times at 0 degrees of rotation (Section 3.3.4). Furthermore, other-centric critical and shared-perspective response times at 90 degrees of rotation are nearly identical (Section 3.3.4).

Table 2
Study 2: Means and standard errors for directional shifts, maximum deviation, and acceleration components at 0, 90, and 180 degrees of rotation.

Rotation	Directional shifts		Maximum deviation		Acceleration components	
	Ego	Other	Ego	Other	Ego	Other
0	1.13 (.07)	1.63 (.05)	14.28 (3.66)	17.84 (1.46)	9.15 (.34)	11.24 (.23)
90	1.22 (.09)	1.67 (.57)	17.15 (4.65)	28.44 (2.47)	9.77 (.43)	11.25 (.26)
180	1.21 (.09)	2.01 (.56)	17.22 (4.39)	25.46 (1.59)	9.96 (.35)	12.72 (.25)

$p < .001$, revealed an increase from 90° to 180° (.32 components), $d = .27$. Also, a statistically significant main effect for responder type, $F(1, 72.44) = 6.72$, $p = .01$, verified that other-centric responders overall had 2.11 more components than egocentric responders, $d = .48$.

3.3.4. Perspective-taking in shared trials

The 0-degree rotated position represents shared perspectives where there is no need to mentally rotate. Despite this, other-centric responders still engage in greater cognitive work, as they are 203 ms slower than egocentric responders (see Section 3.3.2 above). When comparing the shared-perspective trials of egocentric and other-centric responses at 90 degrees of rotation, again, other-centric responders are slower by 172 ms; however, this effect is not statistically significant (Fig. 4). But importantly, the other-centric response times during shared-perspective and critical trials at 90 degrees of rotation did not vary. Similar to Study 1, this result suggests that other-centric responders are consistent across trial types, apparently engaged in a stable strategy of considering the perspective of their partner.

3.4. Brief discussion

When the attributional cues in a communicative context are made more obvious, participants use this information to shape their perspective-taking choice. Here, a participant is told that a partner does not know their location (and thus must infer that the partner is unable to take their perspective). This information was sufficient to bias nearly two-thirds of the participants to an other-centric mode of responding. By doing so, participants are taking on the visuospatial perspective of their partners in assessing how to optimally respond. Furthermore, this mode is sustained throughout the trials, despite the finding that this behavior is comparatively more difficult than egocentric responding, as it was in Study 1 (based on response time and complexity measures).

4. Study 3: Perspective-taking under the assumption that the direction-giver is "real."

Thus far, we have argued that participants adhere to principles of collaboration when interacting with a simulated partner. Moreover, fundamental attributions about the speaker's inability to collaborate tend to lead to greater other-centric responding. In Study 3, we examine this claim in greater detail by now asking: what if participants were to interact with a seemingly real human partner? To achieve this pretense, we use the same experimental stimuli as in Study 1, but add a short, interactive introduction to convince participants that they are connected to a real human being.

In this new scenario, participants have a potentially collaborative partner who can be held responsible for ensuring mutual understanding. And because the partner is initiating the request, and is the one that wants the folder, the burden of collaboration is likely shifted to the speaker – at least to a greater extent than in Study 1 and 2. In these previous studies, there was no way for the recorded speaker to know the participant's perspective, by virtue that the speaker was removed in space and time. And because they, the participants, were the only ones able to adopt an other-centric perspective, they seemingly obliged. In this study we remove the partner's previous limitations, and expect the new attributional information to lead to greater egocentric responding.

4.1. Participants

Eighty participants were recruited from Amazon's Mechanical Turk and were paid 75 cents for their participation. The increase in payment is due to an increase of about 5 min needed to complete the introductory stage of the study. The participants' IP addresses were also different than those in Studies 1 and 2.

4.2. Method

The major addition from Study 1 was to lead participants into thinking that they were remotely connecting to another Mechanical Turk "worker" or Mechanical Turk "requester" (counterbalanced across participants). To establish this ruse, we began with slight modifications in how the study was advertised on Mechanical Turk, as well as in the wording of the initial instructions. Both were altered to provide a cover story that we (i.e., the "Requesters") were testing software that would allow users to engage in real-time audio communication within a Flash-based environment. However, because we were in "the early stages of development," the audio could only be transmitted one-way. Nevertheless, we were most interested in the ability to connect two users, and to have these users perform a joint activity within a shared virtual space. And identical to Study 1, the instructions went onto explain that the activity would require participants to move simulated folders in response to a direction-giver's verbal requests. But unlike Study 1, before participants could proceed, they had to first engage in an extended process of connecting to what would appear to be a "real-life" partner.

In this second step of the introductory stage, participants were directed to press a large button labeled: "CLICK TO CONNECT." Upon clicking, participants were taken to a screen with the message "Connecting to another Turk user, please wait a few seconds..." or "Connecting to a Requester, please wait a few seconds..." displayed near the top. The ellipses in the message above flashed every 500 ms to mimic dynamic updating as the software attempted to "connect" to an outside worker or requester. After approximately 5000 ms, the ellipses stopped blinking and a new screen appeared with the word "CONNECTED" in the upper right-hand corner, and with an empty text box in the middle of the screen. After a brief delay, the male voice in the previous experimental phases of Studies 1 and 2 began to speak in the same tone and volume as in the experimental trials. This male partner reiterated information from the written instructions, which was that he alone could transmit audio but was unable to receive audio from the participant. Next, to (ostensibly) ensure that there was indeed a connection, the male partner then asked the participant to type the code word "CAT" into the empty text box and press the ENTER key. If an incorrect code word was given, the partner repeated the code word with a slightly different intonation. Once the male partner "received" the correct code word, thereby indicating to the participant that the partner could hear him or her, the partner stated that the instructions allowed both of them to proceed. The participant then clicked a button to begin the identical experimental task employed in Studies 1 and 2.

At the completion of the experimental task, several follow-up questions were asked to ensure that the participants believed that they had been connected to a real-life Turk worker or requester. The first and second questions were open-ended responses, with the first question addressing general comments and feedback about the Mechanical Turk task, and the second question asking, "How did you feel about your interaction with your partner?." The third and fourth questions were yes or no responses, asking, "Did you FEEL like you were connected to an actual person?," and "Did you BELIEVE you were connected to an actual person?." Each question was presented in isolation on separate screens.

4.3. Results

We discarded trials from participants who responded that they did not feel/believe that they were connected to a real person, or if a participant indicated in any way that they thought their partner was simulated (e.g., "it sounded like a recording," "the person was a fake"). We achieved a 75% deception rate in this modified task, with 60 out of the 80 participants seemingly convinced that the virtual confederate was indeed a real person.

There were no participants who appeared to be randomly guessing, but one participant did have several trials that exceeded the maximum time limit of ten seconds. This participant was removed. Furthermore, 60 trials, or 2.58% overall, were removed because they exceeded three standard deviations above the response time mean for selecting an initial folder (i.e., 3892 ms).

4.3.1. Patterns of egocentric and other-centric responders

The introduction of a seemingly real partner should change the collaborative attributions that can be made. In the earlier studies, the partner was an ineffectual collaborator, forcing participants to take on the additional work of being other-centric. Now, the partner is capable of carrying the load, allowing participants to delegate work to the partner. In this study, there were 38 (64%) egocentric responders, 17 (29%) other-centric responders, and 4 (7%) mixed responders (based on 70% or more of trials being consistently ego- or other-centric). Thus, there is a higher rate of egocentric responding, $X^2(1) = 8.02$, $p = .004$, suggesting participants were indeed sensitive to the new attributional cues. In comparison, the 20 participants who reported having a simulated partner, and therefore less influenced by the attributional information, were also less likely to respond egocentrically, with a response rate that decreased by 22%.

Lower rates of egocentric responding were also evident in Studies 1 and 2. Compared to the current result, there was a 27% decrease of egocentric responding in Study 1, $X^2(1) = 6.93$, $p = .008$; and a 42% decrease for Study 2, $X^2(1) = 20.55$, $p < .001$. Conversely, in comparing rates of other-centric responding across studies, there was a 24% increase for Study 1, $X^2(1) = 6.87$, $p = .009$; and a 45% increase for Study 2, $X^2(1) = 20.62$, $p < .001$.

4.3.2. Greater processing costs in taking another's perspective

A significant main effect was found for degree of rotation and responder type, both at the $p < .001$ level. Importantly, the interaction term was also significant, $F(2, 1594.32)$, $p = .004$ (see Fig. 5). Simple main effects for degree of rotation at egocentric and other-centric responders showed statistically significant increases of response time for both responder types across degree of rotation: other-centric responders, $F(2, 1594.\ 61) = 28.16$, $p < .001$, and egocentric responders, $F(2, 1593.66) = 14.74$, $p < .001$. These increases occured from 0° to 90°, with other-centric responders 208 ms slower, $p < .001$, $d = .25$; and egocentric responders 78 ms slower, $p = .03$, $d = .08$. There were also increases from 90° to 180°, with other-centric responders 167 ms slower, $p = .004$, $d = .25$; and egocentric responders 99 ms slower, $p = .007$, $d = .18$. Although both egocentric and other-centric responders showed an upward trend across degree of rotation, the cognitive costs of mental rotation enacted a greater cost on other-centric responders. This is evident in the comparison of the fitted regression lines, whereby other-centric responders had a steeper rise in response times, $b = 195$ ms, than that of the egocentric response times, $b = 88$ ms, $F(2, 1353.19) = 48.73$, $p < .001$.

And lastly, simple main effects for responder type at each ground position also show that other-centric responders required more time to respond at 0° (mean difference = 339 ms), $F(1, 63.15) = 9.51$, $p = .003$, $d = .64$; at 90° (mean difference = 468 ms), $p < .001$, $d = .76$; and at 180° (mean difference = 537 ms), $p < .001$, $d = .77$.

4.3.3. Greater processing complexity and competition for other-centric responders

4.3.3.1. Directional shifts. The main effect for degree of rotation was statistically significant, $F(2, 1541.61) = 6.96$, $p = .001$, as was the main effect for responder type, $F(1, 51.51) = 4.82$, $p = .03$. Thus, the increase from 0° to 90° (.08 shifts) and from 90 to 180 (.161 shifts) showed increasing difficulty that is similar for egocentric and other-centric responders; and, overall, the other-centric responders still had more shifts then egocentric responders (see Table 3). However, the interaction term in this model was not statistically significant.

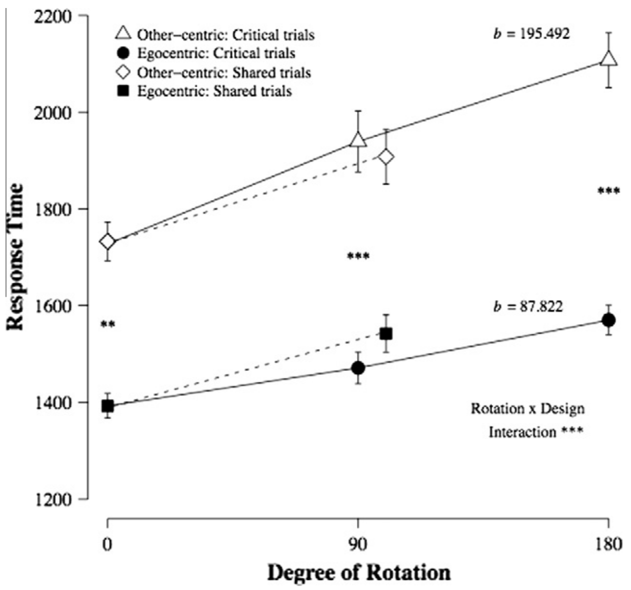

Fig. 5. The critical response times and standard errors of egocentric and other-centric responders at 90 and 180 degrees of partner rotation, and shared-perspective response times at 0 degrees of rotation. Between 0–90°, and 90–180°, other-centric responders take more time, whereas egocentric responders increase from 0° to 90°. However, other-centric responders are generally slower than egocentric responders (Section 4.3.2), including shared-perspective response times at 0 degrees of rotation (Section 4.3.4). Furthermore, other-centric critical and shared-perspective response times at 90 degrees of rotation are nearly identical (Section 4.3.4).

Table 3
Study 3: Means and standard errors for directional shifts, maximum deviation, and acceleration components at 0, 90, and 180 degrees of rotation.

Rotation	Directional shifts		Maximum deviation		Acceleration components	
	Ego	Other	Ego	Other	Ego	Other
0	1.14 (.05)	1.41 (.09)	9.08 (1.14)	16.22 (2.25)	9.23 (.22)	11.56 (.47)
90	1.16 (.07)	1.54 (.12)	9.02 (1.13)	24.01 (3.13)	9.71 (.32)	13.00 (.69)
180	1.29 (.06)	1.73 (.10)	9.73 (.93)	21.64 (2.25)	10.39 (.27)	12.71 (.59)

4.3.3.2. Maximum deviation. Both main effects and the interaction were statistically significant. With further analysis of the interaction, $F(2, 1339) = 3.34$, $p = .04$, simple main effects for degree of rotation at responder type show that only other-centric was statistically significant, $F(2, 1330.17) = 4.88$, $p = .008$, with the greatest deviation occuring from 0 to 90 degrees of rotation (mean difference = 7.79 pixels), $p = .003$, $d = .30$. Simple main effects for responder type at degree of rotation also show that other-centric responders had greater deviation toward the competitor response at 0° (mean difference = 7 pixels), $F(1, 87.31) = 4.97$, $p = .03$, $d = .30$; at 90° (mean difference = 15 pixels), $F(1, 117.61) = 18.80$, $p < .001$, $d = .66$; and at 180° (mean difference = 12 pixels), $F(1, 95.14) = 13.22$, $p < .001$, $d = .56$.

4.3.3.3. Acceleration components. Again, both main effects were statistically significant, but the interaction term was not. Interpreting the main effects, there is an overall increase from 0° to 90° (.96 components) and from 90° to 180° (.67 components), $F(2, 1168.43) = 16.56$, $p < .001$. There is also a greater number of acceleration components for other-centric responders (12.76 components) than egocentric responders (9.78 components), $F(1, 51.30) = 7.38$, $p = .009$.

4.3.4. Perspective-taking during shared trials

As reported in Section 4.3.2 above, and shown in Fig. 5, at 0 degrees of rotation the response times for other-centric responders were 339 ms slower than egocentric responders. For shared trials at 90 degrees of rotation, other-centric responders are again slower, now by 365 ms, $F(1, 52.35) = 8.55$, $p = .005$, $d = .54$. Furthermore, there were no statistically significant differences between shared and critical trials at 90 degrees of rotation. Taken together, these results provide further evidence that other-centric responders are continuing to mentally rotate even when it is not necessary to do so.

4.4. Brief discussion

In Studies 1 and 2, participants interacted with a recorded speaker who was unable to share in the work of forging mutual understanding. In the current study, the same speaker now has the potential to be a viable contributor who shares the participant's goals of collaboration. If participants are sensitive to this information, and are willing to act on it, then previous demands that led to other-centricism are largely diminished. As such, the expected result is a greater percentage of egocentric responders. Indeed, this was found. There was a significant increase of egocentricism when compared to Studies 1 and 2. But like these earlier studies, there were still some who chose to be other-centric – nearly a third of the participants. Like the egocentric participants in Study 1 who appeared to have a stricter criterion for when they would take another's perspective, the other-centric participants in this study might also need more evidence that the speaker is acting with them in mind (thereby allowing the participants to be egocentric). Interestingly, the cognitive ease associated with taking an egocentric perspective does not seem to matter. The other-centric responders still continued to expend more cognitive effort, as shown in the mental rotation analysis for response time, complexity, and competition. Moreover, this effort was sustained over trials, even when visual perspectives between participant and speaker were shared.

5. Additional analysis*:* Right/left vs. back/front trials

In this paper, we have focused on spatial descriptions that occurred in two referential systems, one where objects are situated in terms of one's own bodily coordinates, and the other in which an external agent's coordinates are adopted. The descriptions were based on a common set of referential terms, "right," "left," "front," and "back," that could be used to distinguish folders relative to the viewpoint of either agent. For the right/left terms, a folder occured in conjunction with either an agent's right or left sides, thus intrinsic side was sufficient for identification. For back/front trials, an alternative conceptualization is needed, as folders were always to an agent's front. In these trials, participants are likely assigning the folder nearest an agent (either themselves or their partner) as being the one in "front," or by imposing an intrinsic "front" or "back" to the folder itself. Either way, different conceptual representations might lead to different processing costs, with previous research suggesting that back/front referential terms are easiest to process (e.g., Franklin & Tversky, 1990).

Our goal in this section is to determine whether the processing costs of right/left trials substantially vary from back/front trials; and if so, how this might change our current interpretations of cognitive effort in perspective-taking. To start, we combined the data from Studies 1 to 3 and plotted the response times of egocentric and other-centric participants' right/left and back/front trials (which divides the dataset into two equal parts). Based on visual inspection alone (see Fig. 6), the bulk of the cognitive work appears to be carried by the right/left trials. For these referential terms, there is considerable separation between egocentric and other-centric response times, and when compared to egocentric participants, the other-centric par-

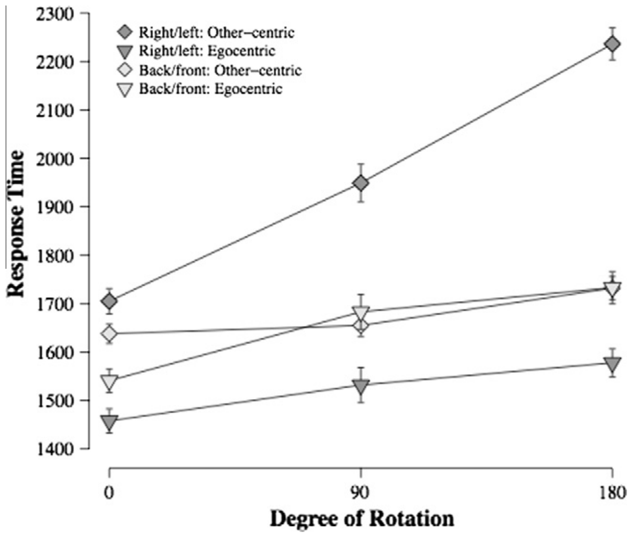

Fig. 6. The right/left and back/front critical response times of egocentric and other-centric responders at 90 and 180 degrees of partner rotation, and shared-perspective response times at 0 degrees of rotation.

Table 4
For Studies 1–3, with back/front and left/right trials, the average increase of response time across degree of rotation (linear slope) and response time differences between egocentric and other-centric responders.

	All trials		
	Study 1	Study 2	Study 3
Slope (b) Other	171 ms ***	132 ms ***	195 ms ***
Slope (b) Ego	76 ms ***	46 ms	87 ms ***
0 (Other–Ego)	183 ms	203 ms	339 ms **
90 (Other–Ego)	232 ms *	142 ms	468 ms ***
180 (Other–Ego)	361 ms ***	380 ms **	537 ms ***

Note: statistical significance is coded as: * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5
For Studies 1–3, with just left/right trials, the average increase of response time across degree of rotation (linear slope) and response time differences between egocentric and other-centric responders.

	Right/left trials		
	Study 1	Study 2	Study 3
Slope (b) Other	271 ms***	257 ms***	386 ms***
Slope (b) Ego	128 ms***	140 ms***	104 ms***
0 (Other–Ego)	228 ms*	210 ms	377 ms**
90 (Other–Ego)	438 ms**	318 ms*	724 ms***
180 (Other–Ego)	620 ms***	703 ms***	990 ms***

Note: statistical significance is coded as: * $p < .05$, ** $p < .01$, *** $p < .001$.

ticipants show a much steeper rise in response times across degree of rotation. Conversely, the back/front trials for egocentric and other-centric responders are essentially the same, with minimal increases over degree of rotation.

The pattern in Fig. 6 does not alter our earlier claims that there are greater cognitive costs in being other-centric, and that these costs are marked by time-consuming visuospatial transformations. However, an update is needed. When mental transformations do occur, they do so between the intrinsic "right" and "left" sides of speaker and participant. This finding also suggests that by combining right/left and back/front trials, we have inadvertently weakened the critical effects reported in Studies 1–3. To examine this possibility, we compare our previous findings with a new round of analysis using just right/left trials. Rather than reporting the entirety of the additional statistical testing, we simply report the response time differences and *p* values. For example, Table 4 shows a summary of the results from Studies 1 to 3, including the average increase of response times across degree of rotation (e.g., *slope* (*b*) *Other*), and the difference in response times between egocentric and other-centric responders (e.g., 0 (*Other–Ego*)). Asterisks by each response time indicate the level of significance. Using the same analytical approach as before, Table 5 provides a snapshot of the results when back/front trials are removed. By comparing these two tables, it is clear that our earlier interpretations from Studies 1 to 3 still hold. Moreover, an even stronger case can be made given the response times in Table 5 (without back/front trials) greatly exceed those shown in Table 4 (with back/front trials),[7] and are still significant despite the considerable loss of statistical power.

Given the improvement for response times, we now have reason to believe that the use of "back" and "front" directions may have also obscured critical effects in the trajectory measures. Because trajectory measures are much more sensitive to subtle changes in response movements, any noise introduced by the back/front trials is likely to be amplified. This sensitivity might explain why the trajectory measures across the three studies were not as robust as the response time results. By removing back/front trials, we expect the trajectory measures to provide

[7] These simple effects analyses are based on overall models with statistically significant interaction terms ($p < .05$).

Table 6
For select trajectory measures, the average increase for each measure across degree of rotation (linear slope) and differences between egocentric and other-centric responders (right/left trials only). The statistically significant interactions between rotation and responder type are also reported.

	Right/left trials			
	Study 2		Study 3	
	Maximum deviation	Acceleration components	Directional shifts	Acceleration components
Interaction	$F(2,993.64) = 2.84$, $p = .05$	$F(2,988.63) = 5.49$, $p = .004$	$F(2,733.76) = 5.55$, $p = .004$	$F(2,731.50) = 11.76$, $p < .001$
Slope (b) Other)	5.57***	1.43***	0.35***	2.33***
Slope (b) Ego	1.62	0.09	0.07	0.27
0 (Other–Ego)	2.96	2.05*	0.23	2.49
90 (Other–Ego)	19.81**	2.12*	0.35	4.92***
180 (Other–Ego)	16.72*	4.37***	0.83***	6.49***

Note: statistical significance is coded as: * $p < .05$, ** $p < .01$, *** $p < .001$.

better support for increased complexity and competition in other-centric response movements.

A new series of analysis was conducted for each of the three trajectory measures for each of the three studies. The general trends found in the earlier studies were again replicated, albeit with increased or similar values for other-centric responders relative to egocentric responders. Because of the large number of additional analyses, and given that they are consistent with our previous conclusions, we highlight only those results that had the largest gains. In these earlier analyses, there were four (out of nine) trajectory measure models that showed no interaction between degree of rotation and responder type. In the new analysis, the interaction term for each model is now statistically significant (see Table 6). A follow-up analysis across degree of rotation reveals evidence of mental rotation for just other-centric responders. And importantly, follow up analysis comparing responder type at degree of rotation (i.e., ground position) shows statistically significant differences between egocentric and other-centric responders at several positions.

6. General discussion

In the introduction, we reviewed the extensive work on the role of perspective-taking in spatial memory and other forms of linguistic and navigational behavior. Yet, in a social context, few have looked at the listener's natural tendencies to disambiguate perspectives in spatial description. In the studies presented here, we created a simple communicative context that required participants to select one of two referents based on a simulated partner's requests. The scenario is modeled after a hypothetical situation where a person, standing next to a table, is asked by someone else for one of two folders that are laid out on the table. If the person making the request says, "Give me the one on the right", and is directly across from the standing person (i.e., addressee), it is unclear if the addressee should assume their own "right" (an egocentric interpretation) or the requester's "right" (an other-centric interpretation).

In Study 1, it is during these open-ended trials, with loose constraints for how to disambiguate, that we evaluated participants' spontaneous perspective-taking behavior. We found that more than half of the participants consistently provided an other-centric response, although this did not statistically differ from number of egocentric responders. Even so, the other-centric perspective was chosen despite a clear processing advantage for egocentric responding, as evidenced by faster response times and less complexity in egocentric response movements.

In Study 2, we sought to better grasp the driving force that might influence participants to be other-centric. We hypothesized that such responding was largely motivated by attributions about the simulated partner's ability (or inability) to contribute to mutual understanding. However, there is always the possibility that the artificial nature of the task also places unintended task demands on a participant. To rule this out, we kept the same design as Study 1, but added a single cue that was directed at influencing partner-specific attributions. Here, the critical attributional cue was a slight change to the instructions, informing participants that their partner does not know where they are located. This information makes it impossible for the partner to consider any perspective other than his own. Following the goals of collaboration, participants who are sensitive to this more explicit information are likely to take on the increased burden of interpreting from the one perspective that is guaranteed to be understood, namely, the simulated partner's. Compared to Study 1, the result should be an increased number of other-centric responders, and a continued cognitive cost of responding other-centrically. As expected, this predicted outcome was confirmed.

Following the same rationale as in Study 2, we sought to manipulate a single attributional cue that would now bias response behavior toward egocentrism. By doing so, a stronger case could be made about the role of partner-specific attributions in influencing perspective-taking behavior. In Study 3, the same design as Study 1 was used, but this time we removed the constraint of having to interact with a simulated partner. Participants now believed that they were receiving directions from a real person – a person who might share responsibility in working toward mutual understanding. Moreover, because this "real" partner was the one making the requests, and did not correct any of the participant's responses, we expected participants to direct most of the responsibility toward the partner. If so, participants are likely to assume the partner is acting other-centrically, thereby choosing egocentric behavior for themselves. Indeed, compared to Study 1, this prediction was supported. We also found a modest number of other-centric responders who were apparently unswayed by the new attributional cue.

In all three studies, the other-centric responders were willing to invest in behavior that was cognitively challenging. In similar research using a spatial perspective-taking task (Schober, 1993; Tversky & Hard, 2009), it is assumed that the increased cognitive effort is the result of mentally rotating to the visual perspective of another. However, without direct evidence to support this claim, it is unclear if participants are in fact embodying the participant's point of view. The experimental task presented here allows us to test this supposition. If participants are mentally rotating, then the greater the offset of one's own visual perspective from that of a partner, the longer it will take to rotate to the partner's perspective. And indeed, this was found for three positions that were offset by an equivalent and increasing magnitude of distance. Other-centric responders were fastest when there was no rotation (shared perspective), but were significantly slower when shared visual perspective was offset by 90°, and even slower when shared visual perspective was offset by an additional 90°. The extent by which these responses were slower also exceeded any slowdowns exhibited by egocentric responders.

These findings suggest that other-centric participants are anchoring to an egocentric frame of reference and making adjustments relative to this frame, a process Zacks and Michelon (2005) calls a *visuospatial perspective transformation*. However, an egocentric visual anchor is not necessarily isomorphic to a socially-motivated egocentric bias. That is, we cannot say that participants are first employing and inhibiting an egocentric bias before considering the perspective of their partner. Our data suggest another possibility. During trials at 0 degrees of rotation, the participant's visual perspective is equivalent to their partner's perspective. These shared visual perspective trials require no mental rotation; thus, if the other-centric responder has been inhibiting an egocentric bias in making a rotation, they are now free from having to do so. As a consequence, response times should be at least equivalent to the egocentric responder. But this is not the case. Other-centric responders are still significantly slower in shared trials. If a strong egocentric bias is not at play, what then causes the slower response times? We argue that the increased time results from an other-centric responder who is still considering what his partner knows, even when visual perspective is aligned. Contrary to Herrmann (1988), Herrmann, Burkle, and Nirmaier (1987) early assertions (as reported by Schober (1993)), participants will indeed "step into the shoes" of their partner even with a shared vantage point. Once a conceptual perspective has been adopted, participants are consistent in the way they apply this perspective in interpreting spatial referents. In a sense, participants are still metaphorically "rotating," even when visual perspectives are aligned.

These findings also have direct implications for the current debate about exactly how partner-specific information is processed during communication. Our claims coincide with Brennan and colleagues' "one-bit" theory that simple yet significant attributional cues can have an immediate effect on behavioral outcomes (e.g., Brennan & Hanna, 2009; Galati & Brennan, 2010), particularly when the cues are easily tracked and introduced early on in the communicative context (Bortfeld & Brennan, 1997; Hanna & Tanenhaus, 2004; Tversky & Hard, 2009). Participants commit wholesale to the elicited perspective (egocentric for Study 3 and other-centric for Studies 1 and 2). Moreover, the use of attributional cues appears to be consistent with Clark and Wilkes-Gibbs' (1986) principle of least collaborative effort, whereby the motivation to consider another's perspective is rooted in a shared responsibility to ensure mutual understanding.

Our results can also be contrasted with another account of perspective-taking behavior that posits language users will consider another's perspective only when a primary egocentric preference becomes unsustainable (Horton & Keysar, 1996; Pickering & Garrod, 2004; Shintel & Keysar, 2009). In this view, when there is a communication breakdown, or a breakdown is likely to occur, speakers (and presumably listeners) will engage in repair strategies that require a more costly other-centric orientation. In the current study, we strove to create a scenario where such repair strategies would be unnecessary. Because a partner's trial-to-trial directions signaled no obvious confusion, participants could respond egocentrically without penalty or communicative mishap. Furthermore, in responding egocentrically, the task could be completed faster – a primary argument for why an egocentric response should be preferred. And given that the social partner only simulates the intentions and presence of an actual person, such task demands could be considered biased toward egocentric responding (see Gerrig, Brennan, & Ohaeri, 2000 for discussion). Yet, despite these contextual influences that arguably favor an egocentric orientation, participants were still willing to act on the attributional needs of an assumed social agent, revealing high rates of other-centric responding in production, as shown by Tversky and Hard (2009), and even here where comprehension is involved.

It also appears that when participants do act egocentrically, particularly when the attributional cues support an egocentric perspective (Study 3), there is some evidence that participants are still tracking information about their partner. As we reported earlier, response times do increase as a partner's position is offset from 0° to 90° and 90° to 180°. Although this increase is far from the required time to make a visuospatial transformation, it does suggest a low-level awareness of conflicting perspectives. This possibility is weakly supported with the egocentric responders in Studies 1 and 2. But because response times in these studies increase from 0 to 90, and are maintained between 90 and 180, it is more likely that responders are merely noticing the locational shift of the recorded speaker from their own vantage point. Thus, an attentional distraction leads to the slight increase of response time, which indicates, at the very least, that egocentric responders are engaged in the task.

Another notable finding is that the high rate of unsolicited other-centric responding is comparable to previous findings (e.g., Galati & Brennan, 2010; Horton & Gerrig, 2002; Schober, 1993). Yet, in these studies, there are production- and task-based constraints that may make an other-centric response more likely. For example, participants might be told ahead of time to consider the perspective of an addressee, or to design utterances in the service of conversational pressures (e.g., to establish common ground), or be allowed to negotiate and receive feedback from their partner. Of course, in the current research, we took a different tack by evaluating perspective-taking behavior as simple comprehension. As with Tversky and Hard's (2009) paradigm, we imposed the most minimal of task requirements for eliciting perspective choice – at least for Study 1. When comparing these similarly matched studies, 53% of our participants and 20% of Tversky and Hard's participants freely chose to be other-centric. Importantly, this difference in response rate also brings up a critical distinction between the two studies. Here, perspective-taking behavior was allowed to stabilize over a series of trials. As in previous research involving a real or simulated social partner, perspective choice is sometimes gradually worked out in the early moments of interaction (Bard & Aylett, 2001; Horton & Keysar, 1996; Roche, Dale, & Kreuz, 2010). Indeed, in our Study 1, 22 other-centric participants, or 51% overall, had between 1 and 3 short-lived "egocentric" responses in the initial trials. If we had assessed perspective-taking behavior after a single trial, these respondents would have been misclassified as egocentric.

There are other differences that make our particular task promising for further exploration. One of these is tracking the temporal dynamics of social perspective-taking. In the present studies, we evaluated simple computer mouse movements which revealed that other-centric responding takes more time to execute, and that the executed movement is characterized by greater directional shifts and decelerations. These latter findings suggest the presence of a processing interference that arises when adopting another's frame of reference. Presumably, a major source of interference is from one's own activated frame of reference (Brown-Schmidt, 2009). Although multiple-frame activation and the primacy of a single activation has received a great deal of attention in ambiguous scene interpretation (Carlson-Radvansky & Irwin, 1994; Carlson-Radvansky & Logan, 1997), it is less clear with social perspective-taking. One issue that we examined in greater detail is whether reference frames are activated sequentially or in parallel (Taylor et al., 1999). If in parallel, we expected to find competition effects during the moment-by-moment changes during the response movement itself. These competition effects can be expressed in paradigms like ours where a competitor and response target are visually co-present (Song & Nakayama, 2009; Spivey & Dale, 2006). Here, we provided a simple measure of how much the movement is displaced toward a competitor en route to a target. For other-centric responders, we found that movements towards a folder designating an other-centric frame were shifted towards a folder designating an egocentric frame. This result suggests both frames were simultaneously activated, but with the other-centric response eventually winning out.

Greater evidence for competition effects, as well as processing costs, can also be had with situational factors that are easily implemented in this task. For example, we can evaluate perspective-taking behavior when there are greater cognitive demands, as in introducing time constraints to respond (as in Bard et al., 2007). We might also find that with stronger attributional cues that favor an other-centric perspective, egocentric responders will have significant difficulty in inhibiting an other-centric frame of reference, perhaps even from the earliest stages of processing. And importantly, this basic task allows us to systematically identify pragmatically relevant cues that might sway the activation and selection of egocentric or other-centric perspectives. It also opens up the possibility of exploring any individual differences that might interact with these factors.

On a final theoretical note, a further possible interpretation of our results is that so-called "default" processes are only one part of the explanatory story of adaptive abilities during interaction. As Schober (1993) demonstrated, the coordinative process of interaction permits rich patterns of adaptation that emerge when one looks for them in appropriately interactive contexts (see also Brennan & Hanna, 2009; Brown-Schmidt, Gunlogson, & Tanenhaus, 2008). Yet, we have shown that even simulated social contexts can induce complete investment in more "difficult" response strategies. This is not simply a matter of monitoring, because the 0-degree trials in our studies still show that participants have embraced the strategy of trial-by-trial transformation for the benefit of an absent but assumed partner. So "defaults" are transformed in socially-embedded contexts, and the "tables are turned," so to speak, because many participants have now organized their interpretive tendencies outside themselves, into the other-centric frame. Our data suggest that a new default, adapted for the benefit of the task, can become that external frame. This suggests that theories of perspective-taking, and partner-specific adaptation in general, need to focus attention on stable strategies in more task-specific ways, rather than seeking generalizations that may overreach, and miss the natural human capacity to adapt cognitive processes in novel circumstances.

Acknowledgments

The research was supported by NSF Grant BCS-0720322 to the second author, and NSF Grant BCS-0826825 to the second and third authors.

References

Amorim, M. A. (2003). "What is my avatar seeing?" The coordination of "out-of-body" and "embodied" perspectives for scene recognition across views. *Visual Cognition, 10*, 157–199.

Baayen, R. H. (2008). *Analyzing linguistic data: A practical introduction to statistics in R*. New York: Cambridge University Press.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*, 390–412.

Bard, E. G., Anderson, A. H., Chen, Y., Nicholson, H. B. M., Havard, C., & Dalzel-Job, S. (2007). Let's you do that: Sharing the cognitive burdens of dialogue. *Journal of Memory and Language, 57*, 616–641.

Bard, E. G., & Aylett, M. P. (2001). Referential form, word duration, and modeling the listener in spoken dialogue. In J. Moore & K. Stenning (Eds.), *Proceedings of the 23rd Annual Meeting of the Cognitive Science Society*. Austin, TX: Cognitive Science Society.

Black, J. B., Turner, T. J., & Bower, G. H. (1979). Point of view in narrative comprehension, memory, and production. *Journal of Verbal Learning and Verbal Behavior, 18*, 187–198.

Bortfeld, H., & Brennan, S. E. (1997). Use and acquisition of idiomatic expressions in referring by native and non-native speakers. *Discourse Processes, 23*, 119–147.

Branigan, H. P., Pickering, M. J., Pearson, J., & McLean, J. F. (2010). Linguistic alignment between people and computers. *Journal of Pragmatics, 42*, 2355–2368.

Brennan, S.E. (1990). *Speaking and providing evidence for mutual understanding*. Unpublished doctoral dissertation, Stanford University, Stanford, CA.

Brennan, S. E., & Hanna, J. E. (2009). Partner-specific adaptation in dialog. *Topics in Cognitive Science, 1*, 274–291.

Brown-Schmidt, S. (2009). Partner-specific interpretation of maintained referential precedents during interactive dialog. *Journal of Memory and Language, 61*, 171–190.

Brown-Schmidt, S., Gunlogson, C., & Tanenhaus, M. K. (2008). Addressees distinguish shared from private information when interpreting questions during interactive conversation. *Cognition, 107*, 1122–1134.

Brunyé, T. T., Rapp, D. N., & Taylor, H. A. (2008). Representational flexibility and specificity following spatial descriptions of real-world environments. *Cognition, 108*, 418–443.

Carlson, L. A. (1999). Selecting a reference frame. *Spatial Cognition and Computation, 1*, 365–379.

Carlson, L. A., & Covey, E. S. (2005). How far is near? Inferring distance from spatial descriptions. *Language and Cognitive Processes, 20*, 617–631.

Carlson-Radvansky, L. A., & Irwin, D. E. (1994). Reference frame activation during spatial term assignment. *Journal of Memory and Language, 33*, 646–671.

Carlson-Radvansky, L. A., & Logan, G. D. (1997). The influence of reference frame selection on spatial template construction. *Journal of Memory and Language, 37*, 411–437.

Clark, H. H. (1996). *Using language*. Cambridge: Cambridge University Press.

Clark, H. H., & Krych, M. A. (2004). Speaking while monitoring addresses for understanding. *Journal of Memory and Language, 50*, 62–81.

Clark, H. H., & Schaefer, E. F. (1989). Contributing to discourse. *Cognitive Science, 13*, 259–294.

Clark, H. H., & Wilkes-Gibbs, D. (1986). Referring as a collaborative process. *Cognition, 22*, 1–39.

Dale, R., & Duran, N. D. (in press). The cognitive dynamics of negated sentence verification. *Cognitive Science*.

Dale, R., Duran, N. D., & Morehead, R. (submitted for publication). Prediction in statistical learning, and implications for the explicit/implicit divide.

Epley, N., Keysar, B., Van Boven, L., & Gilovich, T. (2004). Perspective taking as egocentric anchoring and adjustment. *Journal of Personality and Social Psychology, 87*, 327–339.

Fitneva, S. A., & Song, Y. (2009). The comprehension of "left" and "right" in a referential communication task. In N. A. Taatgen & H. van Rijn (Eds.), *Proceedings of the 31st Annual Conference of the Cognitive Science Society* (pp. 2687–2691). Austin, TX: Cognitive Science Society.

Frank, M. C., & Gibson, E. (2011). Overcoming memory limitations in rule learning. *Language, Learning, & Development, 7*, 130–148.

Franklin, N., & Tversky, B. (1990). Searching imagined environments. *Journal of Experimental Psychology: General, 119*, 63–76.

Fussell, S. R., & Krauss, R. M. (1992). Coordination of knowledge in communication: Effects of speakers' assumptions about what others know. *Journal of Personality and Social Psychology, 62*, 378–391.

Galati, A., & Brennan, S. E. (2010). Attenuating information in spoken communication: For the speaker, or for the addressee? *Journal of Memory and Language, 62*, 35–51.

Gerrig, R. H., Brennan, S. E., & Ohaeri, J. O. (2000). What can we conclude from speakers behaving badly? *Discourse Processes, 29*, 173–178.

Hanna, J. E., & Tanenhaus, M. K. (2004). Pragmatic effects on reference resolution in a collaborative task: Evidence from eye movements. *Cognitive Science, 28*, 105–115.

Herrmann, T. (1988). *Partnerbezogene Objektlokalisation – ein neues sprachpsychologisches Forschungsthema*. Bericht Nr. 25, Arbeiten der Forschergruppe "Sprechen und Sprachverstehen im sozialen Kontext", Heidelberg/Mannheim.

Herrmann, T., Burkle, B., & Nirmaier, H. (1987). *Zur horerbezogenen Raumreferenz: Horerposition und Lokalisationsaufwand*. Bericht Nr. 12, Arbeiten der Forschergruppe "Sprechen und Sprachverstehen im sozialen Kontext", Heidelberg/Mannheim.

Horton, W. S., & Gerrig, R. J. (2002). Speaker's experiences and audience design: Knowing when and knowing how to adjust utterances to addressees. *Journal of Memory and Language, 47*, 589–606.

Horton, W. S., & Gerrig, R. J. (2005). The impact of memory demands on audience design during language production. *Cognition, 96*, 127–142.

Horton, W., & Keysar, B. (1996). When do speakers take into account common ground? *Cognition, 59*, 91–117.

Isaacs, E. A., & Clark, H. H. (1987). References in conversation between experts and novices. *Journal of Experimental Psychology: General, 116*, 26–37.

Kittur, A., Chi, H., & Suh, B. (2008). *Crowdsourcing user studies with Mechanical Turk*. ACM Press. CHI 2008.

Lee, P. U., & Tversky, B. (2005). Interplay between visual and spatial: The effect of landmark descriptions on comprehension of route/survey spatial descriptions. *Spatial Cognition & Computation, 5*, 163–185.

Levelt, W. J. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.

Mainwaring, S. D., Tversky, B., Ohgishi, M., & Schiano, D. J. (2003). Descriptions of simple spatial scenes in English and Japanese. *Spatial Cognition & Computation: An Interdisciplinary Journal, 3*, 3–42. doi:10.1207/S15427633SCC0301_2.

McNamara, T. P., Sluzenski, J., & Rump, B. (2008). Human spatial memory and navigation. In J. Byrne (Ed.). *Learning and memory: A Comprehensive reference* (Vol. 2, pp. 157–178). Oxford: Elsevier.

Michelon, P., & Zacks, J. M. (2006). Two kinds of visual perspective taking. *Perception & Psychophysics, 68*, 327–337.

Miller, G. A., & Johnson-Laird, P. N. (1976). *Language and perception*. Cambridge: Cambridge University Press.

Mou, W., Liu, X., & McNamara, T. P. (2009). Layout geometry in encoding and retrieval of spatial memory. *Journal of Experimental Psychology: Human Perception and Performance, 35*, 83–93. doi:10.1037/0096-1523.35.1.83.

Munro, R., Bethard, S., Kuperman, V., Tzuyin Lai, V., Melnick, R., & Potts, C., et al. (2010). Crowdsourcing and language studies: the new generation of linguistic data. In *Proceedings of the NAACL HLT 2010 Workshop on Creating Speech and Language Data with Amazon's Mechanical Turk*, Los Angeles, CA.

Newman-Norlund, S. E., Noordzij, M. L., Newman-Norlund, R. D., Volman, I. A. C., de Ruiter, J. P., Hagoort, P., et al. (2009). Recipient design in tacit communication. *Cognition, 111*, 46–54.

Perkins, L., & Milroy, L. (1997). Sharing the communicative burden: A conversation-analytic account of aphasic/non-aphasic interaction. *Multilingua, 16*, 199–215.

Pickering, M. J., & Garrod, S. (2004). Toward a mechanistic psychology of dialogue. *Behavioral and Brain Sciences, 27*, 169–226.

Presson, C. C., & Montello, D. R. (1994). Updating after rotational and translational body movements: Coordinate structure of perspective space. *Perception, 23*, 1447–1455.

Quene, H., & van den Bergh, H. (2008). Examples of mixed-effects modeling with crossed random effects and with binomial data. *Journal of Memory and Language, 59*, 413–425.

Roche, J. M., Dale, R., & Kreuz, R. J. (2010). The avoidance of ambiguity during conversation: More than mere priming or mimicry? In S. Ohlsson & R. Catrambone (Eds.), *Proceedings of the 32nd Annual Meeting of the Cognitive Science Society*. Austin, TX: Cognitive Science Society.

Samson, D., Apperly, I. A., Braithwaite, J. J., Andrews, B. J., & Bodley Scott, S. E. (2010). Seeing it their way: Evidence for rapid and involuntary computation of what other people see. *Journal of Experimental Psychology: Human Perception and Performance, 36*, 1255–1266.

Schober, M. F. (1993). Spatial perspective-taking in conversation. *Cognition, 47*, 1–24.

Schober, M. F. (1995). Speakers, addressees, and frames of reference. Whose effort is minimized in conversations about locations? *Discourse Processes, 20*, 219–247.

Schober, M. F. (1998). Different kinds of conversational perspective-taking. In S. R. Fussell & R. J. Kreuz (Eds.), *Social and cognitive psychological approaches to interpersonal communication* (pp. 145–174). Mahwah, NJ: Lawrence Erlbaum.

Schober, M. F. (2009). Spatial dialogue between partners with mismatched abilities. In K. R. Coventry, T. Tenbrink, & J. A. Bateman (Eds.). *Spatial language and dialogue* (Vol. 1, pp. 23–39). Oxford: Oxford University Press.

Shepard, R., & Metzler, J. (1971). Mental rotation of three dimensional objects. *Science, 171*, 701–703.

Shintel, H., & Keysar, B. (2009). Less is more: A minimalist account of joint action in communication. *Topics in Cognitive Science, 1*, 260–273.

Snow, R., O'Connor, B., Jurafsky, D., & Ng, A. Y. (2008). *Cheap and fast – But is it good? Evaluating non-expert annotations for natural language tasks. Presented at the proceedings of the conference on empirical methods in natural language processing*. Stroudsburg, PA: Association for Computational Linguistics.

Song, J. H., & Nakayama, K. (2009). Hidden cognitive states revealed in choice reaching tasks. *Trends in Cognitive Sciences, 13*(8), 360–366.

Sorokin, A., & Forsyth, D. (2008). Utility data annotation with Amazon Mechanical Turk. In *Presented at the IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops*.

Spivey, M. J., & Dale, R. (2006). Continuous dynamics in real-time cognition. *Current Directions in Psychological Science, 15*(5), 207–211.

Taylor, H. A., Naylor, S. J., Faust, R. R., & Holcomb, P. J. (1999). "Could you hand me those keys on the right?" Disentangling spatial reference frames using different methodologies. *Spatial Cognition and Computation, 1*, 381–397. doi:10.1023/A:1010035613419.

Taylor, H. A., & Tversky, B. (1992). Spatial mental models derived from survey and route descriptions. *Journal of Memory and Language, 31*, 261–292. doi:10.1016/0749-596X(92)90014-O.

Taylor, H. A., & Tversky, B. (1996). Perspective in spatial descriptions. *Journal of Memory and Language, 35*, 371–391.

Tversky, B., & Hard, B. M. (2009). Embodied and disembodied cognition: Spatial perspective-taking. *Cognition, 110*, 124–129.

Tversky, B., Lee, P., & Mainwaring, S. D. (1999). Why do speakers mix perspectives? *Spatial Cognition and Computation, 1*, 399–412.

Wilkes-Gibbs, D., & Clark, H. H. (1992). Co-ordinating beliefs in conversation. *Journal of Memory and Language, 31*, 183–194.

Zacks, J. M., & Michelon, P. (2005). Transformations of visuospatial images. *Behavioral and Cognitive Neuroscience Reviews, 4*, 96–118.

Zacks, J. M., Vettel, J. M., & Michelon, P. (2003). Imagined viewer and object rotations dissociated with event-related fMRI. *Journal of Cognitive Neuroscience, 15*, 1002–1018.