Perspective taking and reference frames for spatial and social cognition

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Abstract

When considering the location of objects and places, we often take perspectives in reference to ourselves or someone/something else. Using ourselves as a reference is considered using an egocentric reference frame, while using something external as a reference is considered using an allocentric reference frame. Of interest is the similarity of how these reference frames inform our understanding of both spatial and social cognitive processes. Similar to how we understand objects in relation to ourselves or an external reference, mentalizing and theory of mind processes have also been described using reference frames. Whether there is a common mechanism for using reference frames for processing both spatial and social information is unclear. The present study explored this idea with an online study where participants performed both a spatial and social (i.e., mentalizing) perspective taking task, along with questionnaire gauging personality, visualization ability, and anxiety. Participants who were better at taking someone else's spatial perspective tended to be better at mentalizing. This relationship was not present when taking one's own spatial perspective or when mentalizing was not necessary. We provide preliminary evidence that reference frames contribute to both spatial and social cognitive processes.

Keywords: perspective-taking; reference frames; spatial; social; mentalizing

Introduction

The ability to take someone's perspective is crucial when communicating and understanding where things are in relation to ourselves and others. In other words, perspective taking allows people to understand concepts and situations external to themselves and from another's point of view (Zacks et al., 2000). These two types of perspective taking can be described with reference frames where using our own perspective is an egocentric reference frame, while using another's perspective is an allocentric reference frame (Meilinger & Vosgerau, 2010).

This distinction is not only used in the spatial cognition literature, but also in the mentalizing or Theory of Mind literature (Apperly, 2012). It may be necessary for us to not only analyze spatial information with different reference frames, but also more abstract social concepts. Our tendency to extend our own mental state to other people is a common issue that leads to misunderstandings, and analyzing situations from an external perspective can alleviate these issues (Royzman et al., 2003). What is the relationship between perspective taking for both the spatial and social cognitive domain? Is there a shared mechanism for reference frames for both spatial and social functions? In this paper, we investigated the potential for a common mechanism for reference frames in both spatial and social cognitive functions. This was accomplished with an online study that measured participants' spatial and social perspective taking skills, and with a series of questionnaires for personality trait, visualization ability, and anxiety.

Spatial Perspective Taking

In the topic of spatial cognition, directional relationships or "reference frames" are often characterized as either "egocentric" or "allocentric". Egocentric reference frames organize objects and places in relation to oneself, while allocentric reference frames focus on the relationship between objects and places independent of oneself. While egocentric reference frames provide spatial awareness of immediate surroundings through motor, vestibular, and other senses, allocentric reference frames enable more complex navigation using relationships between landmarks (Burgess, 2008). The organizing of environments into landmarks and various frames of reference assists in spatial navigation tasks and allows us to effectively give directions to others (Taylor & Tversky, 1996). Building these frames of reference helps us also mentally transform our environment to take the perspective of the other objects or people (Zacks et al., 2000).

Different neural structures in the brain have been strongly correlated with certain spatial reference frames. The right fronto-parietal region has often been associated with egocentric representations while the occipito-temporal region has been associated with allocentric representations (Ruggiero et al., 2021). These spatial representations of our environment are based on the idea that our mind creates cognitive maps that organize spatial cues and information. For instance, grid cells in the entorhinal cortex have been found to allow for the formation and development of these cognitive maps (Poucet & Save, 2017). Additionally, cells specialized in encoding head direction, borders, and boundaries within the hippocampus and retrosplenial cortex play an active role in navigation and spatial awareness (Epstein et al., 2017). While theories regarding cognitive maps have often focused on the spatial components in conceptualizing the world around us, additional research has expanded the framework of cognitive maps beyond this to include conceptual and nonspatial components as well (Constantinescu et al., 2016; Peer et al., 2021; Proulx et al., 2016). With the growing evidence of common

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neural structures possibly linking together spatial and conceptual cognitive maps, it remains possible that these cognitive frameworks might also encompass social situations and perspective taking.

Social Perspective Taking; Mentalizing

When taking another's perspective in social contexts, we aim to understand how they perceive the world and what they believe. The act of inferring another's perspective with regards to their beliefs or desires is known as "mentalizing". Mentalizing requires us to understand that others may have access to different information that can influence their subjective perspective (David et al., 2008). Inferring other people's states of mind is a central part to navigating social situations and taking other perspectives (Langdon & Coltheart, 2001).

Similar to spatial perspective taking, the hippocampus has been shown to play a critical role in social cognition and in framing maps of abstract information based on episodic memory. Instead of framing relationships between landmarks in cognitive maps using allocentric references, social cognitive maps rely more on an egocentric perspective when coding the strengths of social relationships (Tavares et al., 2015).

Few studies have investigated whether there exists a connection between perspective taking abilities in spatial and interpersonal contexts; therefore, in this study, we administered both a spatial perspective taking task and a mentalizing task to assess their connection. Given the distinction between egocentric and allocentric reference frames, we predict that people who are better at taking another's spatial perspective (allocentric or "other") will be better at mentalizing, and those who are worse at taking another's spatial perspective (egocentric or "self") will also be worse at mentalizing. If this is the case, it could allow for spatial analyses of how people understand interpersonal relationships or frame negotiations as a navigational problem that can be understood in a more tangible manner.

Personality and Anxiety Differences

While there exist many individual differences in the ways people use reference frames, past research has shown that factors like age and upbringing can potentially impact the tendency to use either of these spatial strategies (Gramann, 2013). Increased anxiety has also been a factor that leads to increased reliance on egocentric information during spatial perspective taking (Todd et al., 2015). When looking at personality factors for both spatial perspective taking and mentalizing, different traits have been found to be correlated with performance in these tasks. Subcategories within the personality trait of agreeableness, such as compassion and non aggression, have been positively correlated with better mentalizing task performance (Allen et al., 2017). However, stronger spatial perspective taking abilities are correlated with higher scores of conscientiousness and emotional stability (Carbone et al., 2019).

Further research is needed to disentangle the complex relationships between these individual difference factors and their connection to spatial and social perspective taking. This study aimed to investigate this connection by having participants complete a set of personality and anxiety questionnaires to evaluate any possible connections to spatial or social perspective taking. We anticipate that one's ability to take both spatial and social perspectives will be dependent on individual differences in anxiety, personality, and visualization. For anxiety, we predict that greater levels of anxiety will be associated with lower spatial perspective taking and mentalizing ability; as suggested by previous literature (Lyons et al., 2018; Maloney et al., 2014).

For personality, we predict that greater agreeableness and conscientiousness will be associated with greater mentalizing and spatial perspective taking ability. This prediction diverges with previous findings where conscientiousness and agreeableness were associated with spatial and mentalizing ability differently (Carbone et al., 2019). If it was the case that spatial and social cognitive abilities share a common mechanism, we would expect similar personality factors to contribute to both in a similar manner (Peer et al., 2021; Proulx et al., 2016).

Our study investigated the potential for common mechanisms for reference frame use in both spatial and social (i.e., mentalizing) contexts. This study was conducted online and participants performed both spatial and social perspective taking tasks, and completed questionnaires that measured personality traits, visualization ability, and anxiety. Our central prediction was that people who are better at taking someone else's spatial perspective would also be better at mentalizing, and that people's ability to take their own spatial perspective would not predict mentalizing ability.

Method

Participants

Two hundred and fifty (147 female, 103 male) undergraduate psychology students at Texas A&M University participated in this online study for course credit. The participants were between 18 and 26 years-old (M = 19). Recruitment was done online using the institution's SONA subject pool. Random assignment was used to counterbalance the order of the perspective taking task and the false-belief task.

Measures

Spatial Perspective Taking Task. The spatial perspective taking task was used to assess how well people can take perspectives in a spatial context. This task was an adaptation of the perspective task used by Todd et al. (2015). It involved participants looking at a picture with two silhouettes of a human head, facing each other, and identifying the direction where a dark circle appears as seen in Figure 1a. A black bar appeared beside one of the two heads which indicated from which head's perspective the participant must respond with ("other" condition). When there was no black bar, the participant had to respond using their own perspective ("self" condition). Accuracy when taking their own perspective was

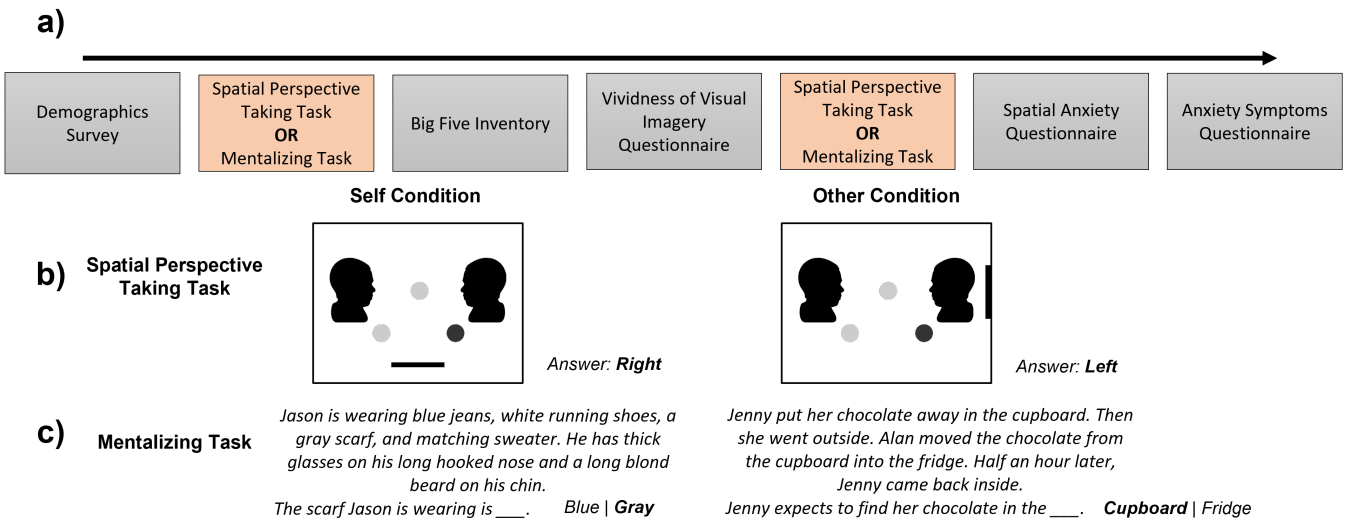

Figure 1: **a)** Illustration of study order of procedures. All participants started with a demographics survey, followed by a random assignment of either the spatial perspective task, or the mentalizing task. After completing the Big-5 inventory and the Imagery questionnaire, participants were assigned the task that was not performed during the second stage of the procedure. Lastly, the spatial anxiety and anxiety symptoms questionnaires were assigned. **b)** Examples of the spatial perspective task. The left figure depicts a trial where participants needed to take their own perspective. The right figure depicts a trial where participants needed to take the perspective of the head on the right side. **c)** Examples of the mentalizing task. The left trial is an example of a question that does not require mentalizing. The example on the right can be solved with mentalizing. The two words at the end are answer choices; bolded words are the correct answers.

used to assess their ability to think egocentrically. Accuracy when taking the perspective of the other two heads were used to assess their ability to think allocentrically. The task consisted of 35 trials, of which 20 trials were the 'other' condition and 15 trials were the 'self' condition.

Mentalizing Task. The mentalizing task was used to assess how well people can take perspectives in a social context. This task was a false-belief task where participants read a short story and then answered a fill-in-the-blank sentence using one of two words that the participants thought best fit the narrative. This task was adapted from (Saxe & Kanwisher, 2003). The task consisted of 12 trials (stories), where 6 were false-belief stories and 6 were controls. To correctly answer the false-belief stories, participants needed to consider the characters' perspective in the story ("other" condition). To correctly answer the control stories, it was sufficient for participants to rely on their own privileged knowledge ("self" condition), instead of considering the mental state of any of the characters.

Big Five Inventory 2. The 60-item Big Five Inventory-2 (BFI-2) (Soto & John, 2017) consists of statements relating to personality traits; openness, conscientiousness, extraversion, agreeableness, and neuroticism. Participants answered using a 5-point Likert scale (from strongly disagree to strongly agree) the degree which they agreed with the statements.

Vividness of Visual Imagery Questionnaire. The 16-item Vividness of Visual Imagery Questionnaire (VVIQ) (Marks, 1973) consists of statements which participants must imagine using their minds and answer using a 5-point Likert scale (no imagery at all to perfectly clear) the degree to how vividly they can visualize the statements. An example statement is "Visualize a rising sun. Consider carefully the picture that comes before your mind's eye." and participants had to imagine "The sun is rising above the horizon into a hazy sky."

Spatial Anxiety Questionnaire. The 24-item Spatial Anxiety Questionnaire (SAQ) (Lyons et al., 2018) consists of statements that describe situations and experiences that involve spatial thinking, for which people may experience anxiety. Participants must imagine being in those situations, and indicate how anxious they would feel. Examples of situations include: "Asked to scan a complex visual scene for a specific item", "Asked to redraw a map from memory", and "Tested on your ability to follow instructions for creating an origami design". They responded using a 5-point Likert scale that ranged between "None at all" to "Very much".

Anxiety Symptoms Questionnaire. The 17-item Anxiety Symptoms Questionnaire (ASQ) (Baker et al., 2019) consists of statements of anxiety symptoms. Participants needed to indicate how intensely and how frequently they experienced each symptom during the past week. Examples of symptoms were: "Anxiety", "Worries", and "Trouble Remember-

ing Things". Participants responded using two 10-point Likert scales; one for the intensity, and the other for frequency. Each scale ranged from 0 to 10, where 0 indicated "None" or "Never" and 10 indicated "Extreme distress" or "All the time".

Procedure

In this online study, all participants used their personal desktop or laptop computers to complete a Qualtrics survey. The survey was divided into five parts. The first part involved answering demographic questions including age, ethnicity, year of study, multilingual status, and handedness. In the second part, participants were randomly assigned to either the spatial or the mentalizing task. If they were assigned to the spatial perspective task, they were first oriented on how to respond with their keyboard. Participants completed 12 practice trials where they were shown a text of "Front", "Left", or "Right", and they were asked to press the corresponding arrow key or with the corresponding "W", "A", or "D" key. Next, they read the instructions for the actual spatial perspective task and proceeded to complete it. If they were assigned to the mentalizing task, they read its instructions and proceeded to complete it. In the third part, participants completed the Big 5 Personality questionnaire and the Vividness of Visual Imagery questionnaire. Next, depending on whether the participant completed the spatial or the mentalizing task during the second part of the survey, they completed the remaining perspective task. During the last part of the survey, participants completed both the Spatial Anxiety Questionnaire, and the Anxiety Symptoms Questionnaire. Finally, participants were notified that they completed the survey, and they were automatically granted credits. This study was designed to take less than 30 minutes to complete.

Results

Performance Differences

Since we counterbalanced the order in which participants performed either the spatial perspective task first or the mentalizing task first, we sought to establish that there was no difference in task performance between the two groups. Of the 250 participants, 120 were assigned to the spatial task first, and performance was measured as the proportion of correctly responded trials. Shapiro-Wilk normality test for performance scores on both the self and the other condition for both the spatial perspective and mentalizing tasks demonstrated non-normal distribution of scores. Correcting significance value for four tests using the Bonferroni method ($\alpha = 0.012$) yielded consistent results.

Next, we performed Wilcoxon rank sum tests with continuity correction for performance from both the self and other conditions for both the spatial and mentalizing task between the two task order groups. This yielded a total of four tests and we adjusted the significance value using the Bonferroni method ($\alpha = 0.012$). All but the "self" condition for the mentalizing task performance was not significantly different between the two task order groups. This shows that participants who completed the mentalizing task during the latter half of the procedure tended to score less than those who started with the mentalizing task. However, spatial perspective task performance was consistent between the task order groups.

Correlational Analysis

Correlational analyses were performed between the "other" and "self" conditions for both the spatial and mentalizing task performance (number of correct trials out of total trials). Figure 2, illustrates the correlation matrix between the 6 possible correlation analyses between the two conditions of the two tasks. Of interest is the unique, positive, yet weak, correlation between the "other" conditions of the spatial and mentalizing tasks ($r(248) = 0.21$, $p < 0.01$, 95% CI [0.08, 0.32]) (Figure 3). This shows that people who tend to perform better during the "other" condition for the spatial task, also performed better during the "other" conditions for the mentalizing task. This was the only statistically significant correlation given the Bonferroni corrected alpha value for four tests ($\alpha = 0.01$). There was no significant correlations between "other" spatial condition and "self" mentalizing condition ($r(248) = 0.14$, $p = 0.03$, 95% CI [0.01, 0.26]), between "self" spatial condition and "other" mentalizing condition ($r(248) = 0.05$, $p > 0.01$, 95% CI [-0.08, 0.17]), and between "self" spatial condition and "self" mentalizing condition ($r(248) = 0.07$, $p > 0.01$, 95% CI [-0.05, 0.19]).

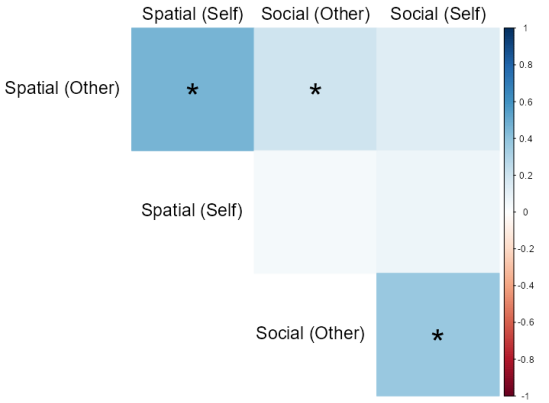

Figure 2: Correlation matrix of performance on the spatial perspective task (Spatial), and the mentalizing task (Social) for both the "self" and "other" conditions.
$*$ Represents significance at $\alpha = 0.012$ ($\alpha = 0.05$ with Bonferroni adjustment for 4 tests).

Regression Analyses

To ascertain whether different individual differences factors contribute to performance differences between the "other" and "self" conditions in both, spatial and social, perspective tasks, we conducted two multiple regressions analyses. For each regression analysis, perspective task performance as assessed by the proportion of correct trials were the criterion

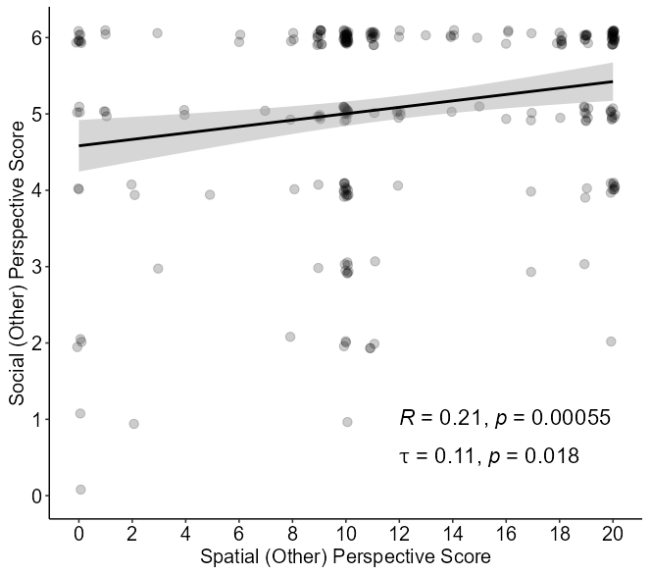

Figure 3: Correlation plot between the spatial perspective task score and the mentalizing task score during the "Other" condition. Both Pearson's and Kendall's correlation coefficients and p-values are displayed.

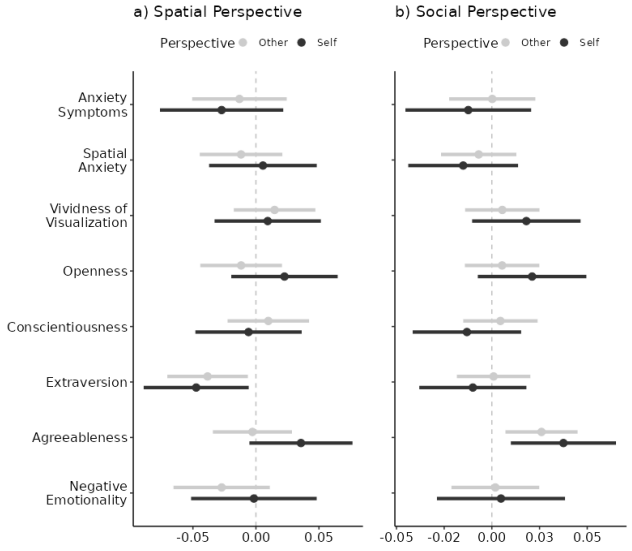

Figure 4: Dot and whiskers plots of multiple regression analyses. Dots represent estimates of coefficients, and whiskers represent 95% confidence interval. **a)** For spatial perspective, extraversion was the only statistically significant predictor with no interaction effect of perspective. **b)** For social perspective (mentalizing), the overall model was not statistically significant. Agreeableness was the only significant predictor, with no interaction effect of perspective.

variables. The predictor variables were scores on the Big 5 personality, spatial anxiety, and anxiety scales along with a perspective interaction factor ("other" and "self"). For ease of interpretation, we mean centered all scales and continuous variables.

The spatial perspective task model was statistically significant ($R^2_{adj} = 0.15$, $F(17,482) = 6.26$, $p < 0.01$) and it showed that greater extraversion predicted worse task performance ($\beta = -0.05$, $p < 0.01$, $\eta^2_p = 0.02$). The only other statistically significant main effect was perspective, where taking one's own perspective predicted better performance ($\beta = 0.22$, $p < 0.01$, $\eta^2_p = 0.15$) (Figure 4a). There were no significant interactions.

The mentalizing task model was not statistically significant ($R^2_{adj} = 0.01$, $F(17,482) = 1.43$, $p = 0.12$) and it showed that greater agreeableness predicted greater task performance ($\beta = 0.03$, $p < 0.01$, $\eta^2_p = 0.03$). There was no statistically significant relationship with any other individual difference factors or significant interactions. (Figure 4b).

Discussion

Results indicate that people who are better at taking someone else's spatial perspective tend to be better at mentalizing. Additionally, we found that extraversion negatively related with spatial perspective taking performance, while agreeableness positively related with social perspective taking performance ormentalizing. However, we did not find evidence that different individual differences factors contribute to perspective taking ability depending on whose perspective is being taken. Overall, the small but unique correlational result supports our hypothesis that people who are better at taking someone else's spatial perspective are also better at mentalizing.

Our main finding of interest was the correlational result, and it gave our best support for connecting people's ability to take spatial and social perspectives (Figure 2 & 3). The unique nature of the correlation between taking someone else's perspective and their ability to mentalize is encouraging. There were no other significant correlations between the "other" perspective conditions of the two tasks. While this result supports our research hypothesis, it is not sufficient evidence to conclude that there is a shared mechanism for reference frames use between spatial and social cognitive functions. It may be the case that there are separate mechanisms for the two domains that happen to perform similar functions. However, our result provides support for a relationship between one's ability to take someone else's perspective in both spatial and social contexts.

Our multiple regression analyses produced weak models for which we can make few interpretations (Figure 4). Contrary to previous studies, conscientiousness did not predict better spatial perspective taking (Carbone et al., 2019). In fact, it predicted worse spatial perspective taking ability. While the mentalizing model was not statistically significant, the positive effect of agreeableness in the mentalizing task was the only effect that aligned with literature (Allen et al., 2017). However, this effect was present regardless of whether the trial needed mentalizing or not. These findings do not sup-

port our prediction that personality traits would contribute to both spatial and social perspective taking ability. Additionally, we could not find support for our hypothesis that anxiety would negatively affect both spatial and social perspective taking.

We did not expect there to be a difference in scores for the self condition of the mentalizing task, depending on the order of procedure. However, participants who performed the mentalizing task during the latter half of the procedure performed worse in the "other" condition of the mentalizing task. This may be due to fatigue where participants become less focused, the further they progress through the tasks. This trend was not present for the spatial perspective task, where there was no difference in performance depending on the procedure order. Perhaps, the spatial task was simpler so that fatigue was less of an issue.

There were limitations to this study. First, our spatial perspective taking task may have been too easy to perform to effectively gauge the variability in ability among the participants. This issue may extend into our mentalizing task where it was too easy to solve, and produced a ceiling effect. Second, the online nature of this study carries its typical limitation where there is no mechanism in place to promote focus and honesty to the assigned tasks. Lastly, our spatial and mentalizing tasks were not ideal at differentiating when people were using a egocentric or allocentric reference frame. When tasked to solve the spatial task from another's perspective, participants can use either an allocentric reference frame, or they may use an egocentric reference frame by taking the place of the other person (Filimon, 2015).

Additionally, the spatial task was two dimensional, and it may have confused the participants when deciding what direction was the correct response. During our social perspective (i.e., mentalizing) task, one condition required participants to mentalize while in another, control, condition they did not need to mentalize. However, all the problems could be solved while the participants were mentalizing. Additionally, the short scenarios for the fill in the black questions persisted while the problem was being solved, further making the task easier to perform.

To address these limitations, we have done a follow-up study that replaced the spatial perspective task used in this study with a spatial orientation task (Hegarty, 2004). Additionally, this follow-up study was conducted both online and in-person to ascertain whether only being online significantly impacted the quality of our data. We hope this line of study will allow us to better understand how reference frames are used and whether there is a shared mechanism for reference frames (Peer et al., 2021; Proulx et al., 2016).

This study contributes to the growing body of work that is attempting to make connections between our ability to understand spatial features like objects and locations, with our ability to understand other people. This paradigm could lead to novel ways of analyzing social interactions or to understand how abstract concepts like people and social relationships are represented in our minds.

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