RELATIONSHIP BETWEEN PERSPECTIVE TAKING WITH SPACE AND PEOPLE

A Thesis

by

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ABSTRACT

Perspective taking is a versatile ability that helps us examine both the spatial and social qualities of things. We take perspectives because it is adaptable to consider both the physical and abstract qualities of objects and people in relation to ourselves and other entities. However, it is not clear whether perspective taking in a spatial or a social context is performed using the same or different cognitive mechanisms. Two studies investigated the relationship between spatial and social perspective taking by measuring participants' spatial and social perspective taking (mentalizing) abilities. Additionally, I administered a series of questionnaires that measured personality traits, visualization ability, spatial anxiety, and general anxiety symptoms, to investigate if there are common individual difference factors that contribute to both perspective taking abilities. I explored whether people who are good at taking spatial perspectives are also better at taking social perspectives. I found a positive relationship between spatial and social perspective taking ability, and that openness was a common personality trait that predicted better spatial and social perspective taking abilities. This suggests that both spatial and social concepts are represented and processed in similar ways, bridging our understanding of these two functions of cognition.

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1. INTRODUCTION

We often take perspectives when we think about space and where things are. Additionally, we imagine taking someone else's perspective when we think about space and the thoughts of other people. Our ability to consider other peoples' thoughts or space is the hallmark of our ability to mentalize, a key function of social cognition. However, there is a gap in the literature on whether our ability to take other's perspectives in space (spatial perspective taking) and our ability to take the perspective of other people (social perspective taking) share the same or similar cognitive processes. To illustrate this gap, I will first review literature about both spatial and social perspective taking, the neural correlates of perspective taking, and how individual differences factors predict perspective taking abilities. Then, I will explain how they motivate my hypotheses and studies.

1.1 Perspective taking

Perspective taking is an intuitive ability that we use to think about the space around us and about how other people think and behave. When I look for an object, I first remember where I last left it, then I infer which direction to go to find it from my perspective. Alternatively, if my partner is looking for something, I'd tell them where it is from their perspective. When thinking for ourselves it is sufficient to use only our own (egocentric) perspective. An egocentric perspective organizes information about our immediate surroundings with visual, motor, and vestibular senses, using ourselves as the reference point (Burgess, 2008). However, if we wish to communicate with other people, it is more adaptable to represent space from an external (allocentric) perspective (Tversky & Hard, 2009). Taking an allocentric perspective allows us to consider spatial layouts from different positions so that we can give a more informative description of space to our audience (Taylor & Tversky, 1996). The key feature of allocentric perspective taking is how it allows us to consider the features and ideas of things in reference to something other than ourselves. This allows us to examine how things look from somewhere else or consider how other people think or feel. Our ability to think about, not only spatial features but also, abstract ideas like emotions, and knowledge states of other people is a central function of social cognition (Frith & Frith, 2007). In summary, perspective taking is an ability that we can flexibly use to consider space in relation to ourselves or someone else.

While the things that we examine when taking perspectives (i.e., spatial, and social) can be different, the functions that perspective taking performs are similar. We can see this in our use of language. We often use scale, distance, or magnitude to describe the relationships between people (Lakoff, 1993; Landau & Jackendoff, 1993; Sinha & López, 2001). Our use of distance or position is often implicated in how much empathy I feel for other people (Cameron & Seu, 2012). Some relatives are "close" relatives and others are "far" relatives. We even use height to describe superiority; having the "high ground" or the "upper hand" corresponds to being advantageous. Because language uses spatial analogies and metaphors to describe interpersonal relationships, it may allow abstract social concepts to be represented spatially, and scrutinized using our spatial faculties to better understand the features of social concepts from an allocentric perspective. This is adaptive because it allows the thinker to consider social relationships from others' perspectives to better comprehend how other people feel about some people. If this overlap is meaningful, I can theorize that our visuospatial faculties are involved when we think about other people to mentalize or empathize. This would allow us to navigate interpersonal struggles by considering the thoughts of the different people involved. This is a key feature of how people can have a Theory of Mind, or how I can mentalize other people's thoughts (Frith & Frith, 2006; Langdon & Coltheart, 2001).

1.2 Neural correlates

Neuroscience research supports a potential connection between social and spatial perspective taking due to the activity of nearly identical brain regions. The right fronto-parietal region was associated with egocentric representations, and the occipito-temporal region was associated with allocentric representations (Ruggiero et al., 2021). Our minds organize spatial cues and information to create cognitive maps (Kitchin, 1994; Tolman, 1948). The grid cell formation in the parahippocampal entorhinal cortex is an important region in the formation of cognitive maps (Poucet & Save, 2017). Cells specialized in encoding head directions and borders & boundaries within the hippocampus and retrosplenial cortex were also implicated in playing an active role in navigation and spatial awareness (Epstein et al., 2017). Hippocampal activation has also been implicated in our use of a cognitive map for social functions (Tavares et al., 2015). Other regions implicated in mentalizing include the posterior end of the superior temporal sulcus (pSTS) and the adjacent temporo-parietal junction (TPJ) (Frith & Frith, 2006). Activities in this region were also implicated in episodic memory and it may play a role in our perspective taking ability (Tavares et al., 2015). These findings suggest that neural regions implicated in spatial perspective taking may also be involved in social perspective taking.

1.3 Individual Differences

Individual difference factors such as personality traits, visualization abilities, and anxiety may impact how we think about space and mentalize (Gramann, 2013; Kliemann & Adolphs, 2018). As such, I will be investigating the relationship between the individual difference factors and both types of perspective taking.

1.3.1 Personality

In terms of the Big Five personality traits (Soto & John, 2017), studies show that subcategories within agreeableness, such as compassion and non-aggression, are positively correlated with better mentalizing ability (Allen et al., 2017). For spatial abilities, higher conscientiousness and emotional stability positively correlate with better performance (Carbone et al., 2019). If spatial and social perspective taking (mentalizing) are related, I could expect that personality traits implicated in either spatial or social perspective taking ability to overlap with each other. Perhaps those who are more agreeable tend to consider the spatial layout of objects from some other position. Or, people who are more conscientious and emotionally stable may be better at considering the thoughts of other people by being able to divert attention away from egocentric information and focus on the thoughts of other people.

1.3.2 Vividness of Visual Imagery

There is mixed evidence for how the vividness of mental imagery relates to how people think about space and people. Some argue that the Vividness of Visual Imagery is a key component of spatial ability because more vivid imagery allows people to better analyze visuospatial concepts using mental imagery (Dean & Morris, 2003). However, others argue that vividness encompasses broad aspects of mental imagery, and not all of them are relevant to our ability to think about space (Dean & Morris, 2003).Nevertheless, if vividness is important for evaluating aspects of visual memory for both spatial or social perspective taking, I can expect greater vividness to predict better perspective taking ability regardless of whose or what type of perspective is being taken.

1.3.3 Anxiety

Both trait and state anxiety are thought to interfere with many cognitive processes; especially by interfering with attentional control (Eysenck et al., 2007). Furthermore, certain types of anxieties, such as spatial anxiety can affect people's cognitive performances for particular types of tasks (Lyons et al., 2018). Similarly, patients with social anxiety disorder were found to have worse mentalizing, or Theory of Mind, ability; characterized by making exaggerated inferences about other people's state of mind (Lyons et al., 2018). Similarly, patients with social anxiety disorder were found to have worse mentalizing, or Theory of Mind, ability; characterized by making exaggerated inferences about other people's state of mind (Hezel & McNally, 2014; Washburn et al., 2016).

The above literature showed that anxiety impedes cognitive functions at large. However, some types of anxieties are localized in what they impede. Thus, it is not clear how anxieties relate to perspective taking abilities. I hypothesize that more anxiety, general or spatial, will predict worse spatial and social perspective taking abilities. Alternatively, more spatial anxiety may only predict worse spatial perspective taking, but not social perspective taking. If the cognitive processes behind both perspective taking abilities are related, I expect the former prediction to be the case.

1.4 Summary

In summary, from the cognitive neuroscience literature, there are multiple connections between spatial and social perspective taking. However, there were few signs of similarities in how individual difference factors contribute to both types of perspective taking abilities. If cognitive maps are versatile enough to represent not only spatial features, but more abstract mental states of other people, and represented using similar neural substrates, I hypothesize: 1) People who are better at taking spatial perspectives are also better at social perspective taking, and 2) individual difference factors that predict spatial perspective taking ability should also predict social perspective taking ability.

To test these hypotheses, I conducted two studies. These studies evaluated participants' skill in taking spatial and social perspectives (mentalizing), self-reported individual difference factors such as personality traits, vividness of mental imagery, and spatial and general anxiety. The first study was conducted remotely (i.e., online without researcher supervision), and the second study was conducted both remotely and in-person. Additionally, the second study included a second spatial perspective taking task to supplement the original spatial perspective taking task from the first study, a modified 3D version of the original spatial perspective taking task, and it excluded the Vividness of Visual Imagery questionnaire.

2. STUDY 1*

2.1 Method

2.1.1 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. There was no attempt to balance any demographic criteria, nor was there any other exclusion criteria.

2.1.1.1 Sample Size Estimation

A statistical power analysis was performed for sample size estimation using the G*Power (Version 3.1.9.7) software (Faul et al., 2009). Because we planned for two multiple regression analyses, we used an effect size of 0.15 which is considered a "medium" effect size according to Cohen (1992). With an α error probability of 0.025, power of 0.95, and 17 predictors, the projected sample size needed was approximately 233. Our final sample size was 250, 17 more than my estimation.

2.1.2 Materials

This study was a remote study and participants used their personal computers to complete a series of tasks using the Qualtrics (Qualtrics, 2022) web interface.

*This section contains material from a previously published work by the author of this thesis. I, the author of this thesis, hold the rights to the contents of the previously published work (Park et al., 2022).

2.1.3 Measures

2.1.3.1 Demographics Questionnaire

Participants reported their age, gender, ethnicity, year of study, handedness, and the number of languages they can speak with a high proficiency.

2.1.3.2 Spatial Perspective Taking Task

The spatial perspective taking task assessed 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). Participants looked at a picture with two silhouettes of a human head facing each other and identified the direction towards one of three circles, as seen in Figure B.1. 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). The target circle was black while the two other circles remained grey. Participants responded using one of three directional arrows (forwards, lift, or right). Accuracy when taking their own perspective was used to assess their ability to use an egocentric perspective. Accuracy when taking the perspective of the other two heads was used to assess their ability to use allocentric perspective. The task consisted of 35 trials, of which 20 trials were the 'other' condition and 15 trials were the 'self' condition. Accuracy on trials were summed together.

2.1.3.3 Social Perspective Taking Task (False-Belief)

The false-belief task assessed participants' social perspective taking ability, and it was adapted from Saxe and Kanwisher (2003). This task was a mentalizing (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. 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' perspectives in the story ("other" condition). To correctly answer the control stories, participants simply relied on their privileged knowledge ("self" condition), instead of considering the knowledge state of other characters. Participants' performance in this task was measured by adding up how many trials they successfully completed in the “Other” condition. The more trials they succeed in the “Other” condition, the better they are at mentalizing. The “Self” condition was a control condition where one’s ability to mentalize should not matter. An example of the task is illustrated in Figure B.2.

2.1.3.4 Big Five Inventory 2

The 60-item Big Five Inventory-2 (BFI-2) (Soto & John, 2017) consisted of statements relating to personality traits; openness, conscientiousness, extraversion, agreeableness, and neuroticism. Participants answered using a 5-point Likert scale (from 1 = “strongly disagree” to 5 = “strongly agree”) to the degree to which they agreed with the statements. A summed score was calculated for each of the big five personality facets. Each of the five facets can have a score up to 60.

2.1.3.5 Vividness of Visual Imagery Questionnaire

The 16-item Vividness of Visual Imagery Questionnaire (VVIQ) (Marks, 1973) consisted of statements that participants must imagine using their minds and answer using a 5-point Likert scale (1 = “no imagery at all” to 5 = “perfectly clear”) to the degree of 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 will need to imagine “The sun is rising above the horizon into a hazy sky” and respond how vividly they imagined it. A summed score across all 16-items was calculated. The most someone can score was 80.

2.1.3.6 Spatial Anxiety Questionnaire

The 24-item Spatial Anxiety Questionnaire (SAQ) (Lyons et al., 2018) consisted 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 ranges from 1 = “None at all” to 5 = “Very much”. A summed score across all 24-items was calculated. The most someone could score was 120.

2.1.3.7 Anxiety Symptoms Questionnaire

The 17-item Anxiety Symptoms Questionnaire (ASQ) (Baker et al., 2019) consisted of statements about 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 Remembering Things”. Participants will respond using two 10-point Likert scales; one for intensity, and the other for frequency. Each scale ranges from 0 to 10, where 0 indicated “None” or “Never” and 10 indicated “Extreme distress” or “All the time”. A summed score across all 17-items was calculated. The most someone could score was 340.

2.1.4 Procedure

After successfully applying to participate using the SONA system, participants were given a URL that led them to a Qualtrics website, where they were briefed about the study. The study was designed to be completed within one 30-minute session. Participants were given the choice to consent and participate in the study, or refuse to consent and end the study. Figure B.3 illustrates the flow of the procedure.

Participants first completed a demographics survey, were randomly assigned to complete either the spatial perspective taking task or the false-belief task, completed the Big Five Personality Inventory (Soto & John, 2017), completed the Vividness of Visual Imagery (Marks, 1973), completed either the spatial perspective taking task or the false-belief task (whichever that was not done previously), completed the Spatial Anxiety Questionnaire (Lyons et al., 2018), completed the Anxiety Symptoms Questionnaire (Baker et al., 2019), and lastly, they were informed of their completion, debriefed and ended the study. Figure B.3 illustrates the procedure.

2.2 Results

2.2.1 Descriptive Statistics

2.2.1.1 Spatial Perspective Taking Task

As shown in Table A.1, participants tended to score better on the "Self" condition (M = 12.32, SD = 3.5, Max = 15) of the spatial perspective taking task, as opposed to the "Other" condition (M = 12.03, SD = 6.05, Max = 20). A paired sample Wilcoxon signed-rank test indicated that this was a statistically significant difference, $z = 3960$, $p < 0.001$. Figure B.4 shows that most participants scored very highly during the "Self" condition with a cluster at the 0.33 chance probability mark. For the "Other" condition, there are clusters towards the top, middle, and the bottom performance. This suggests that there is both a ceiling effect and the possibility that participants were confused with the task, which may have led to poor performance during the task.

2.2.1.2 Social Perspective Taking Task (False-Belief)

As shown in Table A.1, participants tended to score better on the "Other" condition (M = 5.41, SD = 0.84) of the social perspective taking task, as opposed to the "Self" condition (M = 5.09, SD = 1.24). A paired sample Wilcoxon signed-rank test indicated that this was a statistically significant difference, $z = 6294$, $p < 0.001$. Figure B.5 shows that most participants scored very highly during the social perspective taking task overall, and suggests the presence of a ceiling effect.

2.2.1.3 Individual Difference Factors

Table A.2, shows the summary statistics of all the individual difference factors explored in study 1. As shown in Figure B.6, the distributions of the samples were normal with limited deviations towards the tails for some variables. I decided to consider all the samples to be normally distributed for my analyses.

2.2.2 Perspective Taking Order Differences

Because the order in which participants completed the spatial and false-belief task was randomized, I performed Wilcoxon rank sum tests with continuity correction for performance on both the self and other conditions for both tasks to test whether there was an effect of task order. This yielded a total of four tests, and I adjusted the significance value using the Bonferroni method (α = 0.012). Participant performance did not differ regardless of the order of the spatial and social perspective taking task.

2.2.3 Correlational Analysis of Perspective Taking Ability

I expect people who are better at taking spatial perspectives to be better at mentalizing. As such, I expect there to be a positive correlation between participants' performance during the "Other" condition from the spatial perspective task and the "Other" condition from the metalizing task. Additionally, I don't expect there to be correlations between any other pairs of scores between the two behavioral tasks.

Correlational analyses were performed between the "other" and "self" conditions for both the spatial and false-belief task performance (number of correct trials out of total trials). Figure B.7, 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 false-belief tasks ,$r(248) = 0.21$, 95% CI [0.08, 0.32], $p <$ 0.013, (Figure B.8). This showed that people who tend to perform better during the "other" condition for the spatial task, also performed better during the "other" conditions for the false-belief task. This was the only statistically significant correlation given the Bonferroni corrected alpha value for four tests (α = 0.01). There was no other significant correlations and this supports my hypothesis that people's ability to take other people's spatial perspective will selectively correlate with people's ability to take other peoples' social perspective.

2.2.4 Regression Analysis: Investigating Individual Differences

To ascertain whether different individual differences factors contribute to performance differences between the "other" and "self" conditions in both, spatial and social (mentalizing) perspective tasks, I conducted two multiple regressions analyses. For each regression analysis, perspective task performance as assessed by the proportion of correct trials were the criterion 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, I 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, β = -0.05, $p < 0.01$, η^2_p = 0.02. The only other statistically significant main effect was perspective, where taking one's own perspective predicted better performance, β = 0.22, $p < 0.01$, η^2_p = 0.15 (Figure B.9a). The false-belief 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, β = 0.03, $p < 0.01$, η^2_p = 0.03. There was no other statistically significant relationship with any other individual difference factors (Figure B.9b). In summary, there was no support for the hypothesis that there are common individual difference factors that predict both spatial and social perspective taking abilities.

2.3 Discussion

Results indicate that people who are better at taking someone else's spatial perspective tend to be better at mentalizing. Additionally, I found that extraversion was negatively related with spatial perspective taking performance, while agreeableness positively related with social perspective taking performance or mentalizing. However, I 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 my hypothesis that people who are better at taking someone else's spatial perspective are also better at mentalizing.

My main finding of interest was the correlational result, and it gave the best support for connecting people's ability to take spatial and social perspectives (Figure B.7 & B.8).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 my 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 cognitive processes for the two domains that happen to perform similar functions. However, my result provides support for a relationship between one's ability to take someone else's perspective in both spatial and social contexts.

My multiple regression analyses produced weak models for which I can make few interpretations (Figure B.9). 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 false-belief model was not statistically significant, the positive effect of agreeableness in the false-belief 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 support my prediction that personality traits would contribute to both spatial and social perspective taking ability. Additionally, I could not find support for my hypothesis that anxiety would negatively affect both spatial and social perspective taking.

I did not expect there to be a difference in scores for the “Self” condition of the false-belief task, depending on the order of procedure. However, participants who performed the false-belief task during the latter half of the procedure performed worse in the “other” condition of the false-belief 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, my 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 my false-belief task where it was too easy to solve, leading to a ceiling effect. Second, the remote nature of this study carries its typical limitation where there is no mechanism in place to promote focus and honesty to the assigned tasks. Third, my spatial and false-belief tasks were not ideal at differentiating when people were using an egocentric or allocentric perspective. When tasked to solve the spatial task from another's perspective, participants can use both allocentric and egocentric perspective to solve my tasks (Filimon, 2015). Additionally, the spatial task was two-dimensional, and it may have confused the participants when deciding what direction was the correct response. Finally, during my social perspective (i.e., false-belief) 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, four changes were made for my second study. First, my second study used a modified spatial perspective taking task with images of 3D rendered figures and a spatial orientation task (Hegarty & Waller, 2004) was added to supplement the spatial perspective taking task and to test for the construct validity of my 3D perspective task. For ease of differentiation, the modified spatial perspective taking task will be called the "3D perspective taking task". Second, for the false belief task, I made it so participants will not be able to read the short scenario again while responding to the fill in the blank question. Third, study 2 was conducted both remote and in-person to ascertain whether completing an experiment remotely significantly impacted the quality of my data. Finally, study 2 will not include the Vividness of Visual Imagery questionnaire due to time constraints and because it was the least of my research interest when compared to the other individual difference factors.

3. STUDY 2

3.1 Introduction

Study 2 aimed to answer the same research question as study 1 on whether there is a relationship between our ability to take both spatial and social perspectives. My hypotheses were 1) People who are better at taking spatial perspectives are also better at social perspective taking, and 2) individual difference factors that predict spatial perspective taking ability should also predict social perspective taking ability. Additionally, it attempts to amend some of the limitations of study 1 by making 4 changes. First, this study used a modified spatial perspective taking task with images of 3D rendered figures and a spatial orientation task (Hegarty & Waller, 2004) was added to supplement the 3D perspective taking task and to test for the construct validity of my 3D perspective task. Second, the social perspective taking task was modified to be more rigorous. Third, this study was conducted both remotely and in-person to ascertain whether completing an experiment remotely significantly impacted the quality of my data. Lastly, this study excluded the Vividness of Visual Imagery questionnaire due to time constraints and because it was the least of my research interest when compared to the other individual difference factors.

3.2 Method

3.2.1 Participants

Three hundred and eighteen (264 female, 74 male) undergraduate psychology students at Texas A&M University participated in this study for course credit. The participants were between 18 and 26 years-old (M = 18.7). 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. Students who participated in study 1 were not allowed to participate. There was no attempt to balance any demographic criteria, nor any exclusion criteria used. Of these participants, there were 148 remote participants (124 female, 14 male), and 170 in-person participants (120 female, 50 male).

3.2.2 Materials

This study was both a remote and an in-person study using (Qualtrics, 2022) web interface. Remote participants used their personal computers to complete the study unsupervised. In-person participants used desktop computers in a lab with researcher supervision. There were no more than four participants in the lab simultaneously, and they were seated at least one seat apart from one another.

3.2.3 Measures

All measures used in study 2 were identical to those used in study 1, except for not using the Vividness of Visual Imagery questionnaire, changing from the spatial perspective taking task (to the 3D perspective taking task), adding the spatial orientation task, and separating the false-belief scenario from the fill-in-the-blank question so that participants cannot reference the scenario when answering the question.

3.2.3.1 3D Perspective Taking Task

The 3D perspective taking task assessed how well participants can take perspectives in a spatial context. This task was an adaptation of the 2D spatial perspective taking task in study 1, which was an adaptation of the perspective task used by Todd et al. (2015). The modification was made because of my concern that participants were having trouble inferring directions due to its lack of depth cues as discussed in the limitations for study 1. With the new 3D perspective taking task, the stimuli contain gradients and shadows to help infer depth.

Participants looked at a picture with three mannequins in a triangular layout, and they identify the direction of where a dark sphere appeared as seen in Figure B.10. When all the mannequins were gray, participants had to take their own perspective and identify the direction of where the dark sphere is located for themselves; this was the "Self" condition. When one of the mannequins was colored blue, participants needed to take the perspective of the blue mannequin and identified the direction of where the dark sphere was in relation to the blue mannequin; this was the "Other" condition. The task consisted of 45 trials, of which 30 trials were the "Other" condition and 15 trials were the “Self” condition. Participants’ performance was measured as the sum of the number of trials they successfully complete for each of the conditions. The more trials they succeed in the “Other” condition, the better they are at taking someone else’s spatial perspective. The more trials they succeed in the “Self” condition, the better they are at taking their own perspective.

3.2.3.2 Spatial Orientation Task

The Spatial orientation task consisted of 20 trials, and it assessed how well people can take perspective in a spatial context (Hegarty & Waller, 2004). Figure B.11 illustrates an example trial of the task. Participants first studied the layout of objects on a computer screen. On each trial, participants were asked to imagine standing at one of the objects and face another one. Each scenario was illustrated in a circular diagram under the reference image of the global layout. Next, participants were told to imagine pointing at another object. The participant then clicked on a circular diagram of the scenario, where they imagine the object they imagined pointing to would be. The participants had unlimited time and attempt before confirming their selection and moving on to the next trial. However, they were encouraged to complete the task within 15 minutes, and once the trial was submitted, they were not allowed to try again. Participants’ performance was calculated as the absolute angular difference between the true angle to the target object and the angle to where the participants clicked on the screen. Mean absolute angular deviation was used for correlation analysis and absolute angular deviation for each trial were used for regression analysis.

3.2.4 Procedure

The procedure was identical to study 1, with the replacement of the spatial perspective taking task with the 3D perspective taking task, the addition of the Spatial orientation task, and the removal of the Vividness of Visual Imagery questionnaire. Participants signed-up to participate using the SONA system. Remote participants were given a URL that led participants to a Qualtrics website to complete the study. In-person participants came into the lab to complete the study.

Figure B.12 illustrates the flow of the procedure.

Participants completed a demographics survey, then randomly completed either the false-belief task or one of the two spatial perspective taking tasks. If they were assigned to one of the spatial perspective taking tasks, they completed both the 3D perspective taking task and the Spatial orientation task in random order. Next, they completed the Big Five Personality Inventory (Soto & John, 2017). They then completed either the spatial perspective taking tasks or a false-belief task; whichever one that was not performed on the previous step. Then they completed the Spatial Anxiety Questionnaire (Lyons et al., 2018), and the Anxiety Symptoms Questionnaire (Baker et al., 2019). And lastly, participants were informed of their completion, debriefed, and the study was over.

3.3 Results

3.3.1 Descriptive Statistics

3.3.1.1 3D Perspective Taking Task

As shown in Table A.3, participants tended to score better on the "Other" condition (M = 26.16, SD = 7.57, Max = 30) of the 3D perspective taking task, as opposed to the "Self" condition (M = 12.8, SD = 3.3, Max = 15). A paired sample Wilcoxon signed-rank test indicated that this was a statistically significant difference, $z = 21887$, $p < 0.001$. Figure B.13 shows that most participants scored very highly for the task and suggests a ceiling effect.

3.3.1.2 Spatial Orientation Task

Descriptive statistics for the spatial orientation task is shown on Table A.3, M = 38.78, SD = 27.12.

3.3.1.3 Social Perspective Taking Task (False-Belief)

As shown in Table A.3, participants tended to score better on the "Self" condition (M = 5.28, SD = 0.88) of the social perspective taking ask, as opposed to the "Other" condition (M = 4.96, SD = 1.09). A paired sample Wilcoxon signed-rank test indicated that this was a statistically significant difference, $z = 5552$, $p < 0.001$. Figure B.14 shows that most participants scored very highly for the task and suggests a ceiling effect.

3.3.1.4 Individual Difference Factors

Table A.5 shows the summary statistics of all the individual difference factors between locations. As shown in Figure B.15, the distributions of the samples were normal with limited deviations towards the tails for some variables. I decided to consider all the samples to be normally distributed for my analyses.

3.3.2 In-Person versus Remote Participant Differences

To begin my analysis, I investigate whether there were any differences in performance between the in-person and remote participants. Using the Wilcoxon rank sum test, I found that in-person participants ($M = 27.9$, $SD = 4.85$) tended to score higher than remote participants ($M = 24.2$, $SD = 9.46$) during the "other" condition of the 3D perspective taking task, $W = 15076$, $p < 0.01$, Figure B.16. This was also the case for the spatial orientation task where in-person participants ($M = 33.1$, $SD = 19.8$) tended to perform better than remote participants ($M = 42.5$, $SD = 27.2$), $W = 10466$, $p < 0.01$, Figure B.17. This might have been because the in-person participants were being monitored by the experimenter and so were more motivated to focus on the tasks. I did not find any difference between in-person and remote participants for the false belief task performance. The summary statistics of participant task performance and individual difference scores are shown in Tables A.4 and A.5.

3.3.3 Correlational Analyses of Perspective Taking Tasks

To investigate whether spatial and social perspective taking abilities are similar. I tested whether the scores between spatial perspective taking and social perspective taking tasks correlated. I expected to see better scores in both the 3D perspective task and the spatial orientation task to relate with better false belief task score. Additionally, I expect the scores to correlate only when they pertained to perspective condition where participants took the perspective of someone else. This resulted in 10 comparisons, and I adjusted the significance α to 0.005 using the Bonferroni method. As illustrated in Figure B.18. I found a significant correlation between the spatial orientation task and the "other" condition for the 3D perspective taking task, $r_\tau(318) = -0.23$, and the "other" condition for the false-belief task, $r_\tau(318) = -0.21$. There was a significant correlation between the "other" condition of the 3D perspective taking task and the "other" condition of the false-belief task, $r_\tau(318) = 0.2$. There were significant correlations between the 3D "other" condition and the social "self" condition, $r_\tau(318) = 0.14$, and between the social "other" condition and the 3D "self" condition, $r_\tau(318) = 0.14$. The significant correlations between the "Other" conditions of both 3D and social perspective taking tasks and the spatial orientation task supports my first hypothesis.

3.3.4 Correlation Differences Between In-Person & Remote Participants

As mentioned in a previous section, I found that there were significant differences in performance between perspective condition in the 3D perspective taking task. Thus, I conducted a different set of correlational analyses for participants who participated in-person and those who participated remotely. As seen in Figure B.19 (In-Person) and Figure B.20 (Remote), there were different results between the two analyses. The significant correlation between the "Other" condition of both the 3D perspective taking task and the social perspective taking task was not present for in-person participants. Additionally, the significant correlation between the "Other" condition of the 3D perspective taking task and the spatial orientation task was not present for in-person participants. However, the significant correlation between the "Other" condition of the social perspective taking task and the spatial orientation task was present for in-person participants. This correlation supports my first hypothesis that people who are better at taking other's social perspective are also better at taking spatial perspectives. The implication of these findings are further explored in the discussion section.

3.3.5 Regression Analyses

To investigate if individual difference factors such as the Big Five personality traits, anxiety symptoms, and spatial anxiety related to both spatial and social perspectives taking ability, I fitted regression models for all three task performance measures.

3.3.5.1 3D Perspective Task

I fitted a linear mixed probability model (estimated using REML and BOBYQA optimizer) to predict the proportion of correct trials with the fixed effect variables of gender, perspective, location, the Big Five personality facet scores, the Anxiety Symptoms Questionnaire score, and the Spatial Anxiety Questionnaire score. I modeled the interaction between perspective, gender, and location factors, the interaction between perspective and the Big Five personality facet scores and the two anxiety questionnaire scores, and the interaction between perspective and each of the personality and anxiety scores (formula: score $\sim$ perspective * gender * location + perspective * (BF_Os + BF_Cs + BF_Es + BF_As + BF_Ns + ASQs + SAQs)). The model included perspective, participant id, and each trial as random effects (formula: $\sim$perspective | id, $\sim$1 | trial). The model's total explanatory power was substantial (*conditional* R^2 = 0.51) and the part related to the fixed effects alone (*marginal* R^2) was of 0.06. The model's intercept was 0.88 (95% *CI* [0.85, 0.91], *t*(10773) = 61.20, *p* < .001). All scores were standardized and mean centered at the population level. 95% Confidence Intervals and p-values were computed using a Wald t-distribution approximation. Gender, openness, conscientiousness, anxiety symptoms, and spatial anxiety were the statistically significant main effects. The only significant interaction was between perspective and conscientiousness. These effects are illustrated in Figure B.21.

The effect of gender was positive, β = 0.04, 95% CI [0.01, 0.07], *t*(10773) = 2.92, *p* = .003, η_p^2 = 0.04. On average, controlling for all other personality and anxiety scores at the mean level, male participants (*EMM* = 0.94, *SE* = 0.02) scored 10 percentage points more than female participants (*EMM* = 0.84, *SE* = 0.01) in the 3D perspective task score (*Z* = 4.62, *p* < 0.001).

The effect of openness was positive, β = 0.02, 95% *CI* [1.73e-04, 0.04], *t*(10773) = 1.98, *p* = 0.048, η_p^2 = 0.02. On average and controlling for all other personality and anxiety scores at the mean level, one standard deviation increases in openness score related to 3 percentage point increase in the 3D perspective task performance.

The effect of neuroticism was positive, β = 0.04, 95% *CI* [9.66e-03, 0.07], *t*(10773) = 2.61,

p = 0.009, η_p^2 = 0.03. On average and controlling for all other personality and anxiety scores at the mean level, one standard deviation increases in neuroticism score related to a 4 percentage point increase in the 3D perspective task performance.

The effect of anxiety symptom questionnaire score was negative, β = -0.03, 95% *CI* [-0.06, -1.95e-03], $t(10773)$ = -2.09, p = 0.036, η_p^2 = 0.02. On average and controlling for all other personality and anxiety scores at the mean level, one standard deviation increases in anxiety symptoms score related to 5 percentage point decrease in the 3D perspective task performance.

In summary, gender, openness, neuroticism, and anxiety symptoms had significant effects on 3D perspective task performance. There were no interactions with perspective, where any of the individual difference factors related differently with 3D perspective task performance depending on who's perspective the participant took. This limits the support for my second hypothesis where implications for these findings apply to the perspective taking ability in general regardless of whose perspective is being taken.

3.3.5.2 Spatial Orientation Task

I fitted a linear mixed model (estimated using REML and nloptwrap optimizer) to predict the absolute angular difference with the fixed effect variables of gender, location, the Big Five personality facet scores, the Anxiety Symptoms Questionnaire score, and the Spatial Anxiety Questionnaire score. I also modeled the interaction between both gender and location and each of the personality and anxiety scores (formula: angDiff $\sim$ location * gender + gender * (BF_Os + BF_Cs + BF_Es + BF_As + BF_Ns + ASQs + SAQs)). The model included participant id, and each trial as random effects (formula: $\sim$1 | id, $\sim$1 | trial). The model's total explanatory power is substantial (*conditional* R^2 = 0.37) and the part related to the fixed effects alone (*marginal* R^2) is of 0.06. The model's intercept, was at 32.59 (95% *CI* [26.29, 38.88], $t(3780)$ = 10.15, p < .001). All scores were standardized and mean centered at the population level. 95% Confidence Intervals and p-values were computed using a Wald t-distribution approximation. It showed that gender and openness were significant effects. These effects are illustrated in Figure B.22.

Gender was a single significant and negative main effect (β = -8.87, 95% *CI* [-12.35, -

5.38], $t(3780) = -4.99$, $p < .001$, $\eta_p^2 = 0.08$). On average, controlling for all other personality and anxiety scores at the mean level, male participants (*EMM* = 22.2, *SE* = 4.25) performed better than female participants (*EMM* = 40.4, *SE* = 3.07) by demonstrating smaller absolute angular deviation by approximately 18.3 degrees, $t(300) = 5.05$, $p < 0.01$, $d = 0.57$. Openness was a significant but small negative effect ($\beta = -3.78$, 95% *CI* [-7.03, -0.53], $t(3780) = -2.28$, $p = 0.023$, $\eta_p^2 = 0.02$). One standard deviation increase in openness related to approximately 3.78 degrees decrease in absolute angular deviation; an improvement in performance.

In summary, gender and openness were the two factors that predicted spatial orientation performance. Openness was a consistent factor that improved performance for both the 3D perspective task and the spatial orientation task.

3.3.5.3 Social Perspective Taking Task (False-Belief)

I fitted a linear mixed probability model (estimated using REML and nloptwrap optimizer) to predict the probability for correct trials with the fixed effect variables of gender, perspective, location, the Big Five personality facet scores, the Anxiety Symptoms Questionnaire score, and the Spatial Anxiety Questionnaire score. I also modeled the interaction between perspective, gender, and location factors. And I modeled the interaction between perspective with the Big Five personality facet scores and the two anxiety questionnaire scores (formula: score $\sim$ perspspective * gender * location + perspective * (BF_Os + BF_Cs + BF_Es + BF_As + BF_Ns + ASQs + SAQs)). The model included participant id, and each trial as random effects (formula: $\sim$1 | id,$\sim$1 | trial). The model's total explanatory power was weak (*conditional* R^2 = 0.13) and the part related to the fixed effects alone (*marginal* R^2) was 0.02. The model's intercept was at 0.84 (95% CI [0.80, 0.89], t(2862) = 35.48, p < .001). All scores were standardized and mean centered at the population level. 95% Confidence Intervals and p-values were computed using a Wald t-distribution approximation. There was no significant interaction in the model. I found a significant positive effect of openness, a negative effect of extraversion, and a negative of location. These effects are illustrated in Figure B.23.

The effect of openness was positive ($\beta = 0.03$, 95% *CI* [0.02, 0.05], $t(3791) = 4.23$, $p <$

.001, $\eta_p^2 = 0.06$). On average and controlling for all other personality and anxiety scores at the mean level, one standard deviation increases in openness score related to 3 percentage point increase in the false belief task score. The effect of extraversion was negative (β = -0.02, 95% *CI* [-2.47e-04, -0.04], *t*(2862) = -1.99, *p* = 0.047, $\eta_p^2 = 0.23$). On average and controlling for all other personality and anxiety scores at the mean level, one standard deviation increases in extraversion related to 2 percentage point decrease in the false belief task score.

The effect of location was negative (β = -0.02, 95% *CI* [-0.05, -2.17e-03], *t*(2855) = -2.15, *p* = 0.032, $\eta_p^2 = 0.02$). On average and controlling for all other personality and anxiety scores at the mean level, in-person participants (*EMM* = 0.87, *SE* = 0.025) were more likely to correctly respond on a trial than remote participants (*EMM* = 0.82, *SE* = 0.028), *t*(229) = 2.15, $p < 0.05$, *d* = 0.15.

The significant effect of location motivated me to test a different model to test if any personality or anxiety scores interacted with location. The new model was identical to the original model with the inclusion of location and perspective as interaction factors, and it performed almost identically to the original model, $\chi^2(14) = 21.18$, $p > 0.05$.

There were consistent effects of location and openness, but no effect of extraversion. Additionally, there were interactions of location with neuroticism and anxiety symptoms. It revealed that neuroticism had a positive effect for remote participants (β = 0.04, 95% *CI* [0.005, 0.08], *t*(222) = -2.68, $p < 0.01$) where 1 standard deviation increase in neuroticism related to 4 percentage point increase in probability of correctly responding in the false belief task. It also revealed that anxiety symptoms score had a negative effect for remote participants (β = -0.04, 95% *CI* [-0.07, -0.01], *t*(222) = 2.24, $p < 0.05$) where 1 standard deviation increase in anxiety symptoms score related to a 4 percentage point decrease in probability of correctly responding in the false belief task. There was no interaction between perspective (“Self” Vs “Other) and any of the individual difference factors. This suggests that each individual difference factor relates to the task performance in a similar manner regardless of what perspective was being taken.

3.3.5.4 Summary

In summary across all three regression analyses, I found that openness was a common predictor across all three perspective tasks. This provides some support for my second hypothesis that there are shared individual difference factors that predict better performance for both spatial and social perspective taking ability. However, the non-significant effect of perspective limits the support for my second hypothesis where implications for these findings apply to the perspective taking ability in general regardless of whose perspective is being taken.

3.4 Discussion

The purpose of study 2 was to ameliorate the limitations of study 1 and test my original hypotheses of 1) People who are better at taking spatial perspectives are also better at social perspective taking, and 2) individual difference factors that predict spatial perspective taking ability should also predict social perspective taking ability.

3.4.1 Relationship Between Our Ability to take Spatial and Social Perspectives

With regards to the correlation analysis, I found that scores during the “Other” perspective condition of the 3D perspective task and the false belief task correlated with each other and with the spatial orientation score. There were weaker correlations between the “self” condition of the 3D perspective task and the “other” condition of the false belief task, and vice versa. I did not expect to find these small but significant correlations across the perspective conditions. This may be due to a ceiling effect on the false belief task, as it may be too easy to solve. Thus, the scores may not be variable enough to express a differing performance due to the perspective condition. However, the unexpected correlations were weaker than the other correlations, and I observed that there were no positive correlation between one’s ability to use their own perspective in either spatial or social context with their spatial orientation ability. The selective correlation between taking someone else’s perspective and spatial orientation gives overall support for the possibility that both spatial perspective taking and mentalizing recruit our spatial faculties.

Another interesting finding was the different correlation results between the in-person and remote participants. I found that the "Other" condition of my 3D perspective task correlated with the "Other" condition of the false-belief task for only the remote participants, Figure B.19 & B.20. Figure B.24 better illustrates the aforementioned difference in correlation. This scatter plot shows how in the remote condition there was a greater prevalence of poor performers for both the 3D perspective taking task and the false-belief task. It is unclear as to why this difference exists. One possibility is that remote participants were less focused on the tasks, which increased the difficulty of the task. Additionally, This suggests that my 3D perspective task is able to relate spatial and social perspective taking ability in a remote setting, but not in an in-person setting. This change in significance was also present between the "Other" condition of the 3D perspective task and the spatial orientation task. This suggests that the construct validity of my 3D perspective task is only valid in a remote setting. Anyhow, it seemed that the spatial orientation task (Hegarty & Waller, 2004) is the more robust measure of perspective taking ability, and it was able to preserve the relationship between the "Other" condition of the false-belief task irregardless of location.

3.4.2 Relationship Between Individual Difference Factors and Perspective Taking Abilities

With regards to the regression analyses, I found that openness was a consistent personality facet that predicted better performance across all three perspective taking tasks. I also found an effect of gender was present for both spatial perspective tasks (3D perspective task, and the spatial orientation task).

The effect of gender was consistent with previous literature, male participants showed better spatial ability (Reilly & Neumann, 2013). The effect of gender was not seen for the false belief task. Previous studies showed that female participants tend to score higher on Theory of Mind scales (Adenzato et al., 2017). This may be due to limitations of the simplicity of the false belief task, leading to a ceiling effect where there is a dearth of variability for gender to be a significant predictor. Next, I will compare the regression analyses with the results of study 1, and further discuss their implications.

In comparing the results to study 1, I did not replicate the positive effect of extraversion from the prior 2D perspective task. Instead, I found that openness and neuroticism predicted better spatial perspective taking ability. This is not consistent with the findings by Carbone et al. (2019) who showed that conscientiousness related to slightly better spatial ability. Carbone et al. (2019) used a combination of mental rotation, perspective taking and visuo-spatial memory tasks to assess spatial ability. It is likely that the 3D perspective task was limited to assessing the perspective taking aspect of spatial ability, and it did not capture other relevant aspects of spatial ability to replicate the findings of Carbone et al. (2019). However, the result found in study 2 was partially consistent with the longitudinal study by Schaie et al. (2004). They observed that openness and agreeableness were significant predictors of spatial orientation ability.

The 3D perspective task results also showed a surprising opposite effect between neuroticism and anxiety symptoms score. The negative effect of anxiety symptoms was not present in study 1, but it was consistent with literature showing that anxiety is related to a decrease in a variety of cognitive abilities (Eysenck et al., 2007; Maloney et al., 2014). However, I did not expect to see a positive effect of neuroticism, as it is often associated with disruptive experiences such as anxiety, anger, and self-consciousness (Costa & McCrae, 1980). However, Beckmann et al. (2013) showed that an elevated level of neuroticism is related to better task performance. It was also found that the positive effect of state neuroticism is even greater the more demanding the task is (Smillie et al., 2006). The opposite effect of the two factors is likely due to neuroticism being only partly related to anxiety. Neuroticism is also composed of other facets such as emotional volatility and depression (Soto & John, 2017).

Results from the spatial orientation task showed that openness was the only individual difference factor that predicted spatial perspective taking ability. This was consistent with the 3D perspective taking task, the false belief task, and the findings by Schaie et al. (2004). However, it was not consistent with the result of 2D perspective task from study 1 and the findings by Carbone et al. (2019). This may be due to their broader assessment of spatial ability beyond spatial orientation.

Results of the false belief task showed an absence of the effect of agreeableness seen in study 1 and this was inconsistent with previous literature (Allen et al., 2017; Nettle & Liddle, 2008). Instead, I observed a positive effect of openness and a negative effect of extraversion. A neuroimaging study by Beaty et al. (2016) showed a robust relationship between openness and efficient information processing in the default mode network which has been implicated in a variety of cognitive processes including theory of mind reasoning. Openness is described as one's range of perceptual, cognitive, and affective experiences (Soto & John, 2017). As such, openness may be a personality trait that is very conducive for mentalizing.

However, it is unclear why I did not observe an effect of agreeableness in study 2. Agreeableness involves compassion, respect and trust of others, and it should be the most conducive personality trait for mentalizing ability (Soto & John, 2017). It may be the case that the theory of mind task used in the study did not require the level of agreeableness required for authentic social interactions. The task involved reading a short scenario and responding to a binary choice. There is no need to extend a significant level of respect or compassion to the fictional characters to solve the questions at a reasonable performance. Inserting oneself and considering how "I" should be treated may be sufficient to solve the problems. If this was the case, traits relating to openness may be sufficient to solve the false belief task.

It is unclear why extraversion would negatively predict false belief ability. Extraversion is characterized by sociability, assertiveness, and energy level (Soto & John, 2017). As such, it is surprising that a personality trait that is oriented to social interaction is negatively associated with mentalizing ability. However, Alvi et al. (2020) also found a similar negative relationship between extraversion and performance in three social-cognitive tasks. There is a surprising dearth of research into how the extraversion personality trait is related to social cognitive functions like mentalizing. Broader implications of the findings will be discussed in the general discussion.

4. GENERAL DISCUSSION

Perspective taking is an ability used in a variety of contexts. And it is not clear whether their similarities are only in their function or if there are similarities at deeper levels. I investigated if both spatial and social perspective taking (mentalizing) abilities are predicted by common personality traits and anxieties. I conducted two studies where participants performed spatial perspective taking tasks and a false-belief task and questionnaires to measure their big five personality, anxiety symptoms, and spatial anxiety. I hypothesized that 1) people who are better at taking spatial perspectives are also better at social perspective taking, and 2) individual difference factors that predict spatial perspective taking ability should also predict social perspective taking ability.

Between the two studies, I was able to support my first hypothesis and found that people's ability to take someone else's spatial perspective was correlated with their ability to take someone else's social perspective. However, the results were correlational, and I cannot say with confidence whether there is a meaningful connection between perspective taking abilities or whether the relationship was spurious. I was only able to partially support my second hypothesis and I found that openness was a statistically significant predictor for both spatial and social perspective taking ability. However, with the lack of interaction with the perspective manipulation, it is inconclusive. I can only claim that openness is a personality trait that can predict spatial and social perspective taking ability, regardless of whether you are taking someone else's or your own perspective.

It is unclear as to why openness was a common personality that predicted better spatial and social perspective taking abilities. However, openness is a personality that involves traits such as imagination, intelligence, and absorption (DeYoung, 2015). It also involves the tendency to go out of one's way to experience different things both physically and intellectually (Soto & John, 2017). It may be the case that people who tend to be more curious and put themselves out into the world and interact with people are the types of people who better train their ability to both navigate space and think about what other people are thinking. Further investigation is needed to better understand and test these potential relationships.

There was one notable limitation to my studies. There were ceiling effects for both the 3D perspective task and the false belief task. The tasks may have been too trivial, and most participants performed very well, leading to low variability in the scores among those who perform well. This leads to most of the variabilities to emerge from the low performers and this increases the risk of false significance (Austin & Brunner, 2003). Future studies should use tasks that can better measure the participants' perspective taking abilities at a higher difficulty.

In conclusion, I was able to find correlational evidence that there is a positive relationship between spatial and social perspective taking ability, and that openness is a common personality trait that predicted better spatial and social perspective taking ability. These studies contribute to the growing body of work that tries to investigate whether our spatial cognitive functions are used for social cognitive abilities such as mentalizing (Peer et al., 2021). Future studies could explore what concepts can be represented spatially, and social interactions may be modeled in novel ways. For example, negotiations could be modeled as a spatial navigation problem where the end goal is a mutual agreement, and dead ends are topics or ideas that are not beneficial for either party; this type of analogy may sound familiar to some readers. Further investigation into this topic may reveal that our spatial analogies are not just analogies, but real ways ideas are represented in our minds.

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APPENDIX A

TABLES

Table A.1: Study 1: Perspective Taking Task Performance Summary Statistics.

Perspective Taking Task	N	Mean	SD	Min	Max
Spatial (Other)	250	12.03	6.05	0	20
Spatial (Self)	250	12.32	3.5	0	15
Social (Other)	250	5.41	0.84	2	6
Social (Self)	250	5.09	1.24	0	6

Table A.2: Study 1: Individual Difference Factors Summary Statistics.

Individual Difference Factor	N	Mean	SD	Min	Max
Openness	250	43.16	7.55	22	60
Conscientiousness	250	41.76	8.05	21	58
Extraversion	250	40.24	8.2	18	58
Agreeableness	250	44.12	7.05	21	59
Neuroticism	250	36.88	9	14	58
Anxiety Symptoms	250	128.87	61.3	0	293
Spatial Anxiety	250	41.51	17.22	0	89
Vividness	250	3.65	0.74	1	5

Table A.3: Study 2: Perspective Taking Task Performance Summary Statistics.

Perspective Taking Task	N	Mean	SD	Min	Max
Angular Deviation	318	38.78	27.12	6.4	131.09
3D (Other)	318	26.16	7.57	0	30
3D (Self)	318	12.8	3.3	0	15
Social (Other)	318	4.96	1.09	1	6
Social (Self)	318	5.28	0.88	2	6
Location	318				
... In-Person	170	53%			
... Remote	148	47%			

Table A.4: Study 2: Task Performance Summary Statistics by Location.

Perspective Taking Task	N	Mean	SD	Min	Max
Location: In-Person					
Angular Deviation	170	33.65	22.12	6.4	119.35
3D (Other)	170	27.85	4.85	0	30
3D (Self)	170	12.92	3.33	0	15
Social (Other)	170	4.99	1.03	1	6
Social (Self)	170	5.38	0.75	3	6
Location: Remote					
Angular Deviation	148	44.67	30.95	8.8	131.09
3D (Other)	148	24.22	9.46	0	30
3D (Self)	148	12.67	3.27	0	15
Social (Other)	148	4.92	1.16	1	6
Social (Self)	148	5.17	1.01	2	6

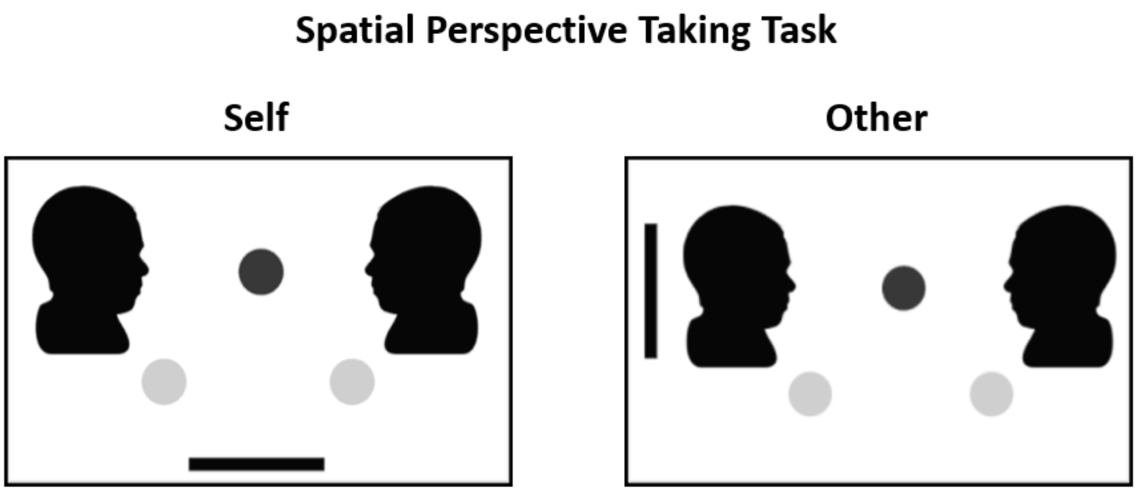
Table A.5: Study 2: Personality and Anxiety Summary Statistics.

Individual Difference Factor	N	Mean	SD	Min	Max
Location: In-Person					
Openness	170	44.24	7.62	26	60
Conscientiousness	170	43.68	7.15	23	59
Extraversion	170	41.42	8.87	20	60
Agreeableness	170	46.21	6.32	26	59
Neuroticism	170	36.01	9.06	13	59
Anxiety Symptoms	137	111.93	50.35	16	255
Spatial Anxiety	170	42.36	16.92	2	90
Location: Remote					
Openness	148	42.78	8.07	18	60
Conscientiousness	148	45.18	7.35	26	60
Extraversion	148	39.11	7.99	17	57
Agreeableness	148	44.29	6.29	31	58
Neuroticism	148	36.62	9.18	14	57
Anxiety Symptoms	103	134.57	59.14	0	283
Spatial Anxiety	148	45.98	18.08	0	96

APPENDIX B

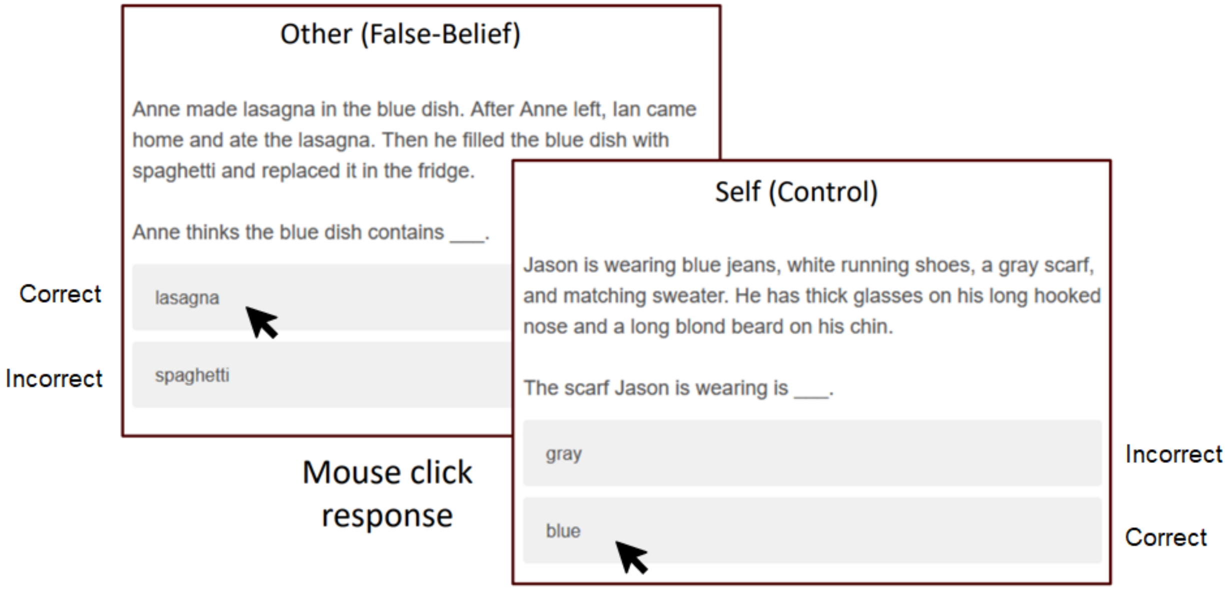
FIGURES

Figure B.1: Examples of the spatial perspective taking task.



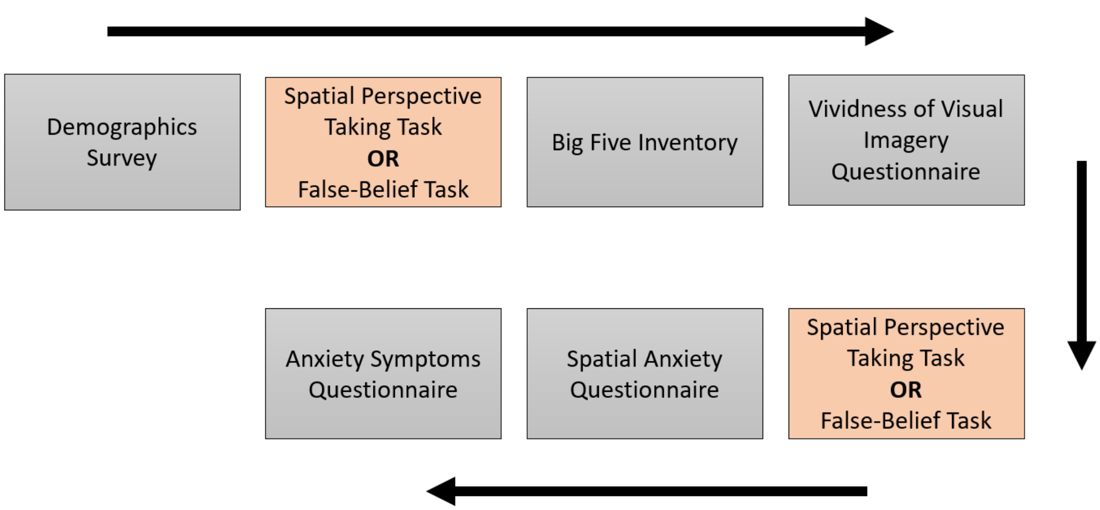
Note. The left figure depicts a trial where participants need to take their own perspective. The correct answer is to press the “forward” arrow. The right figure depicts a trial where participants need to take the perspective of the head on the left side. The correct answer is to press the left arrow.

Figure B.2: Examples of the False-Belief task.



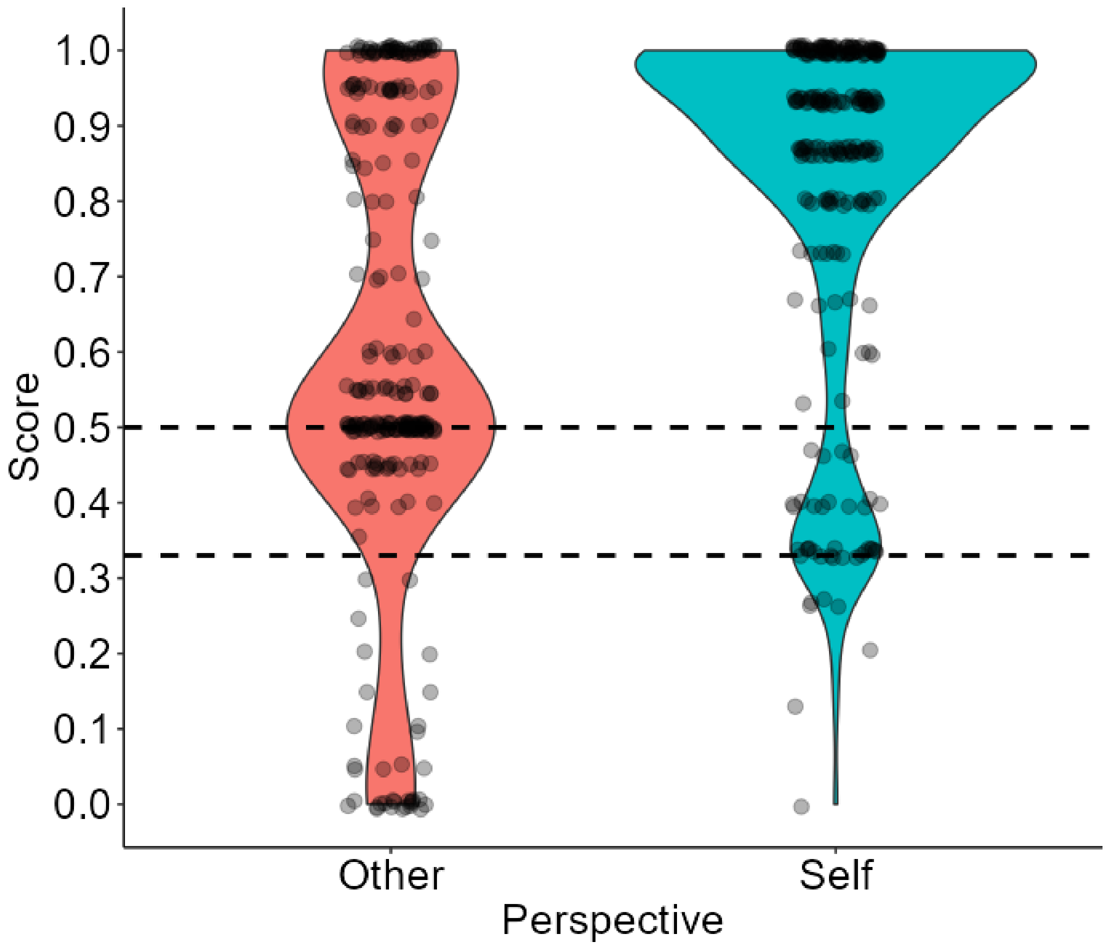
Note. The example of the left side is for the "Other" condition where participants need to consider the mental state of one of the characters in the story. The example on the right is for the "Self" condition where no mentalizing is required, and participants should be able to solve by considering only their own knowledge. The bold text represents two choices participants need to respond by clicking one of them.

Figure B.3: Study 1: Procedure flow diagram.



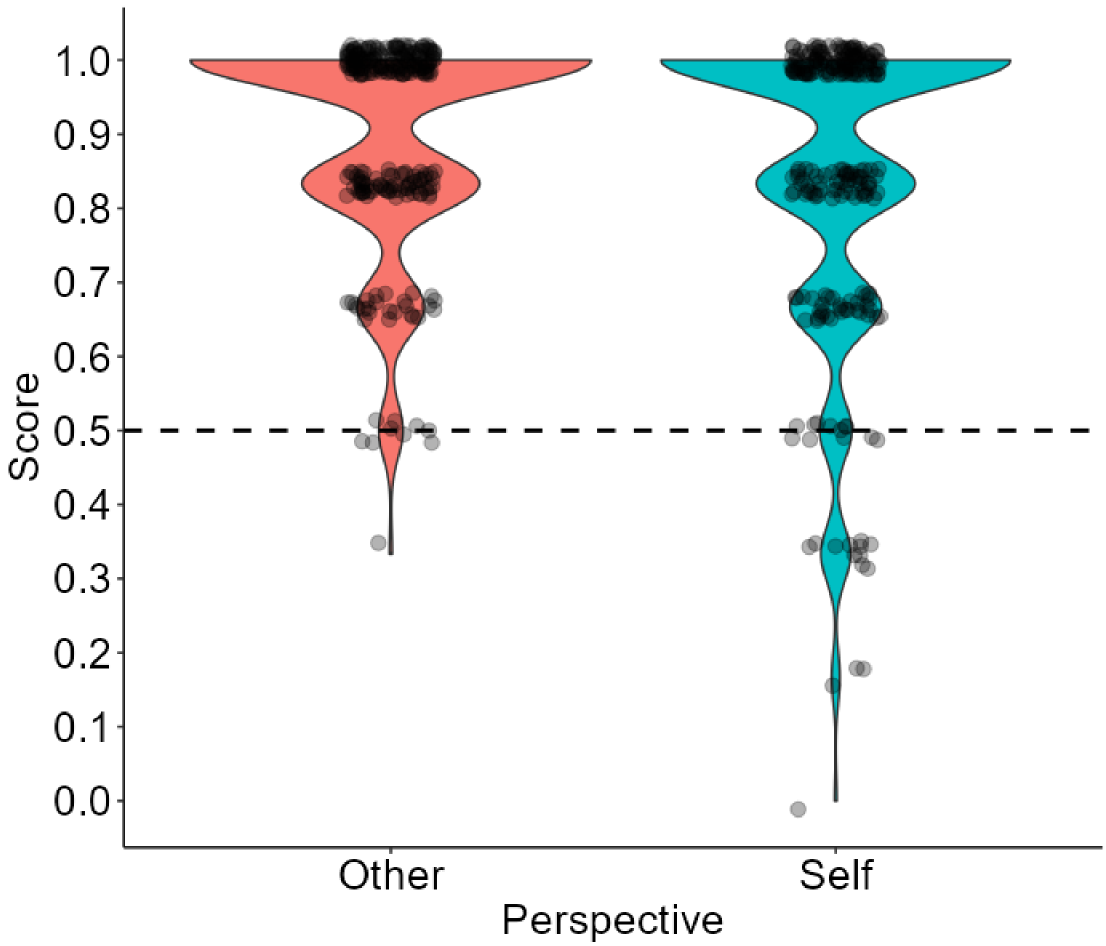
Note. The highlighted boxes describe randomized tasks. The second highlighted box assigns the task that was not assigned in the first highlighted box of the procedure.

Figure B.4: Study 1: Violin Plots of Spatial Perspective Taking Task.



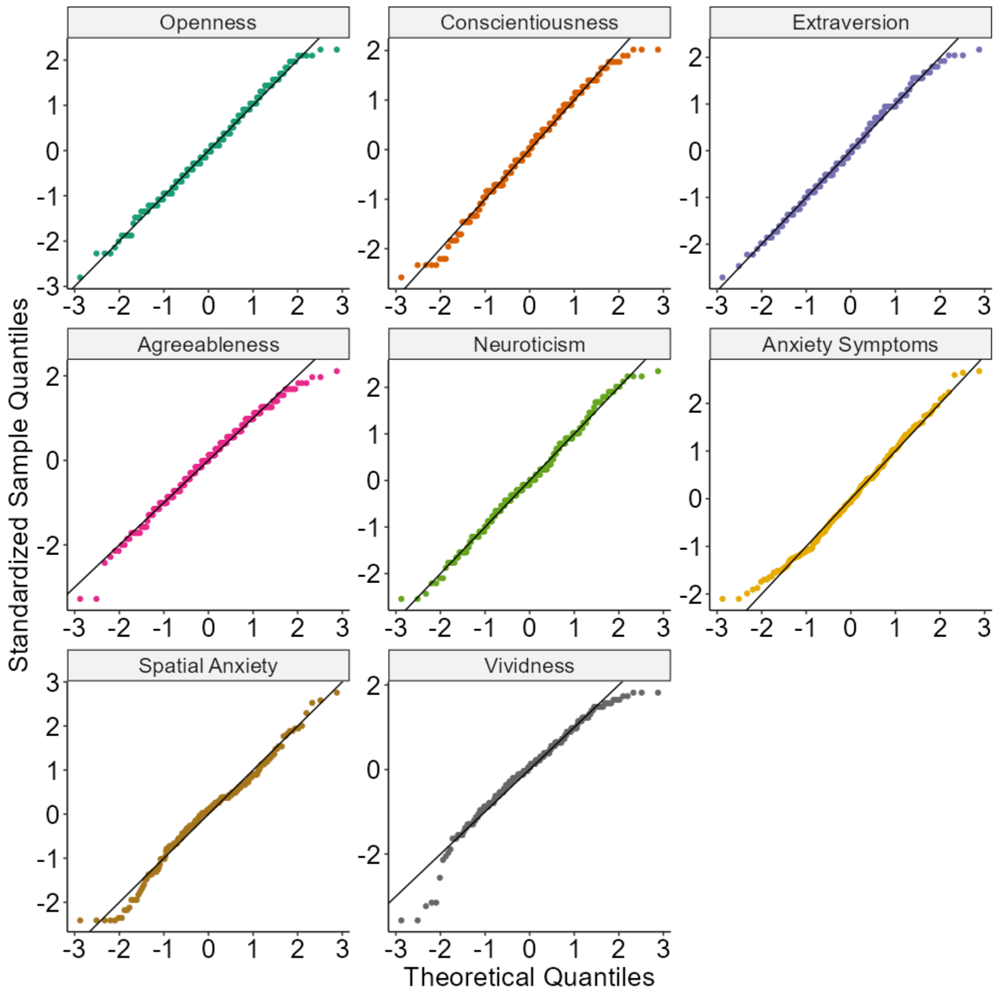
Note. Violin plots show ceiling effect for the spatial perspective taking tasks. Dashed-lines represent chance performances for the spatial perspective taking task. Chance performance for the "Other" condition is 0.5, and the chance performance for the "Self" condition is 0.33.

Figure B.5: Study 1: Violin Plots of False-Belief Task.



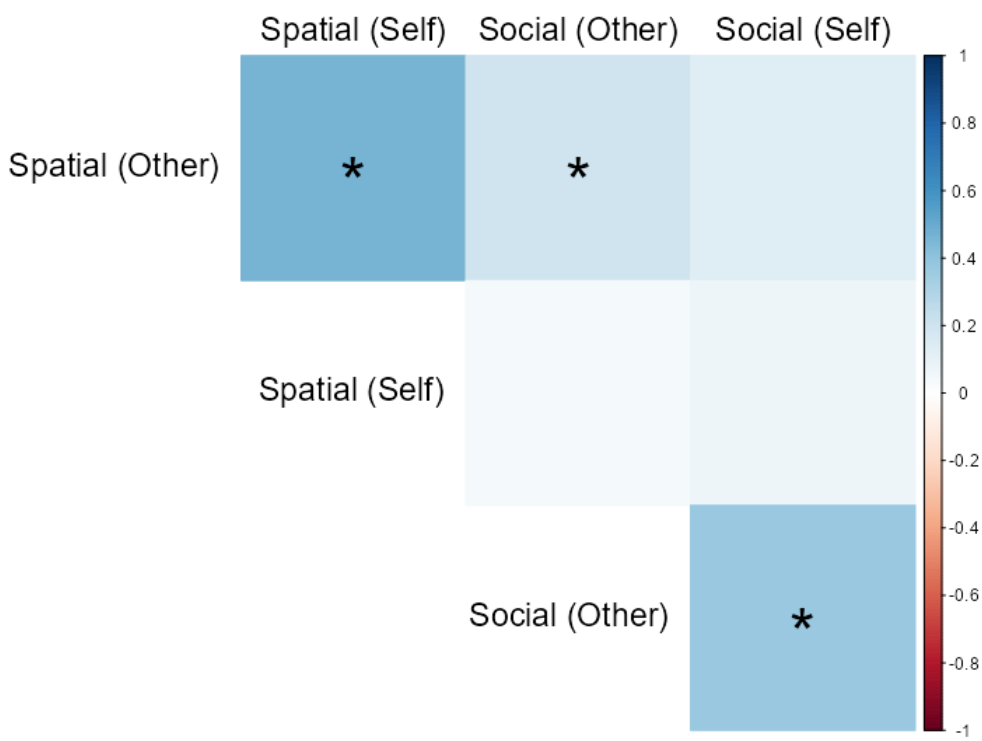
Note. Violin plots show ceiling effect for the social perspective taking tasks. Dashed-lines represent chance performances for the false-belief task. Chance performance for the "Other" and "Self" condition is 0.5.

Figure B.6: Study 1: QQ Plots of Individual Difference Factors.



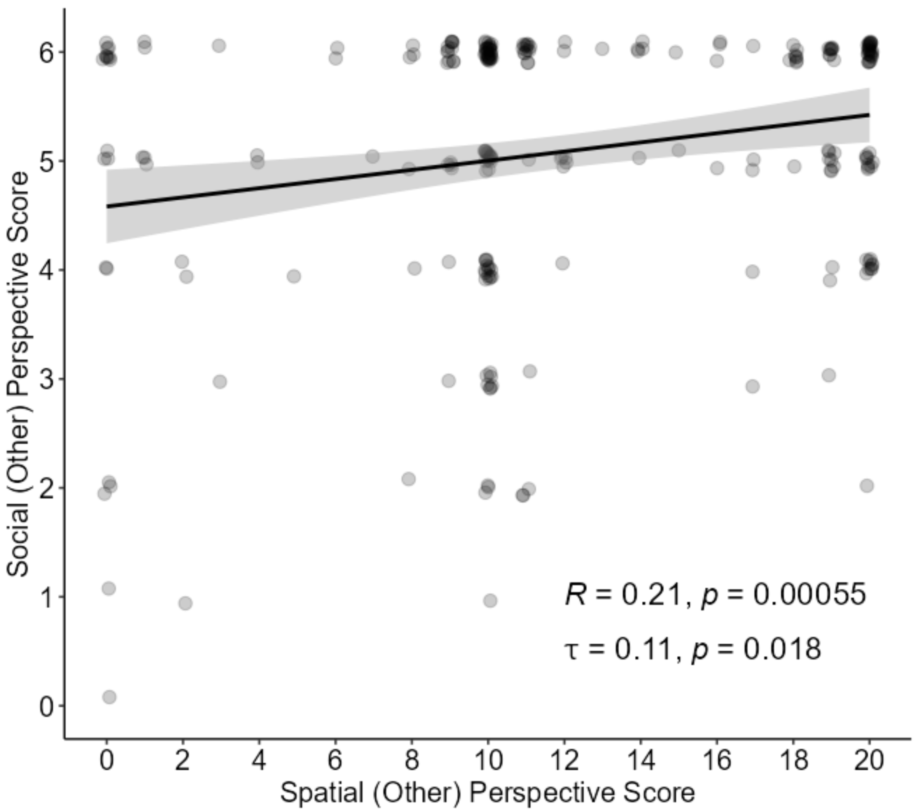
Note. Most variables had normally distributed samples. Variables such as vividness, spatial anxiety, anxiety symptoms, and agreeableness showed some deviations towards the tails. I decided to consider all the distributions to be normal for analyses.

Figure B.7: Study 1: Correlation matrix between spatial perspective task and false-belief task.



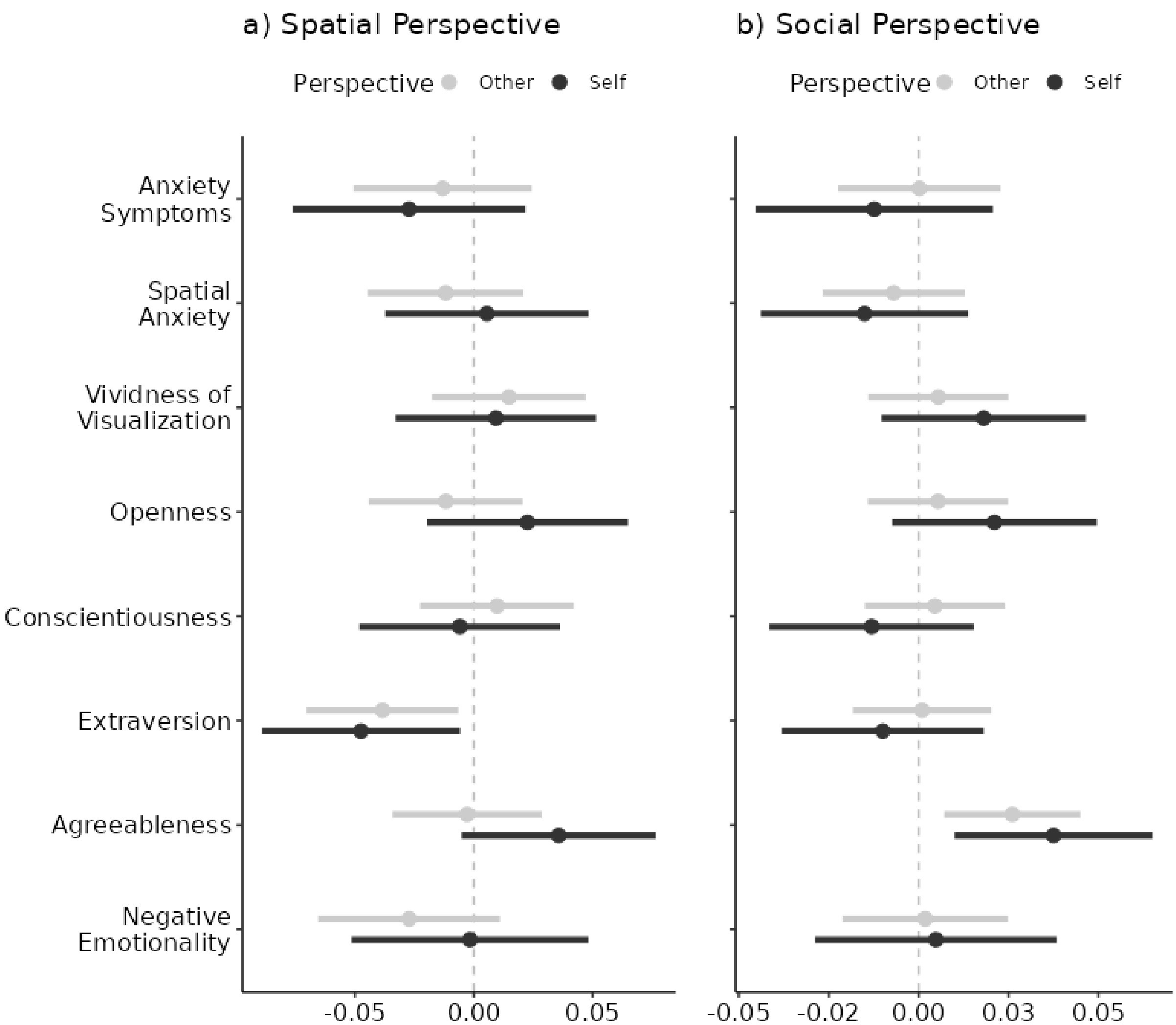
Note. Correlation matrix of performance on the spatial perspective task (Spatial), and the false-belief task (Social) for both the ”self” and ”other” conditions. Of note is the significant correlation between the “Other” spatial perspective taking score and the “Other” false-belief score.
$*$ Represents significance at α = 0.012 (α = 0.05 with Bonferroni adjustment for 4 tests.)

Figure B.8: Study 1: Scatter plot of the “Other” condition of the spatial perspective taking task and the false-belief (social) task.



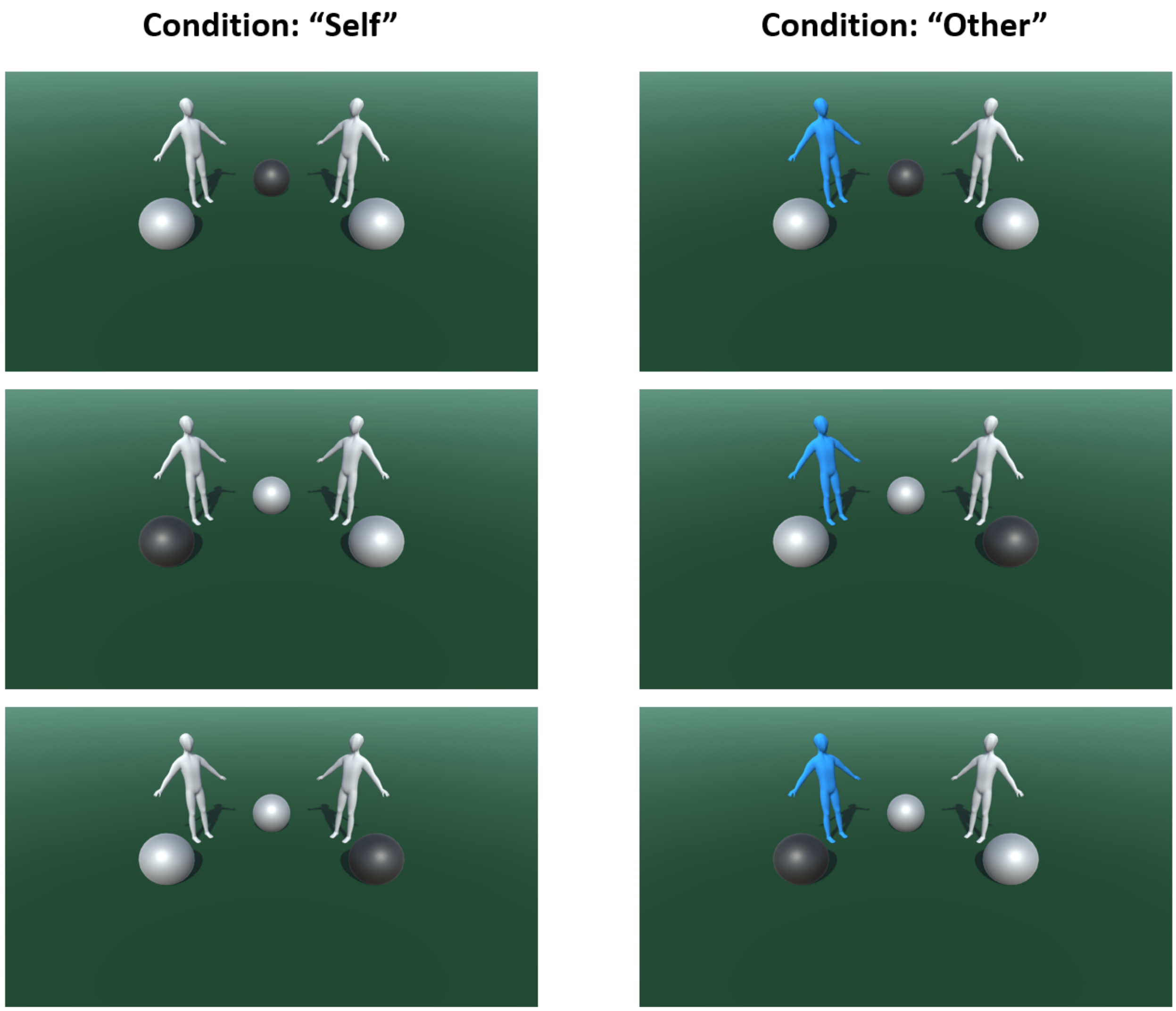
Note. Correlation plot between the spatial perspective task score and the false-belief task score during the ”Other” condition. Both Pearson’s and Kendall’s correlation coefficients and p-values are displayed.

Figure B.9: Study 1: Dot and whiskers plots of multiple regression analyses.



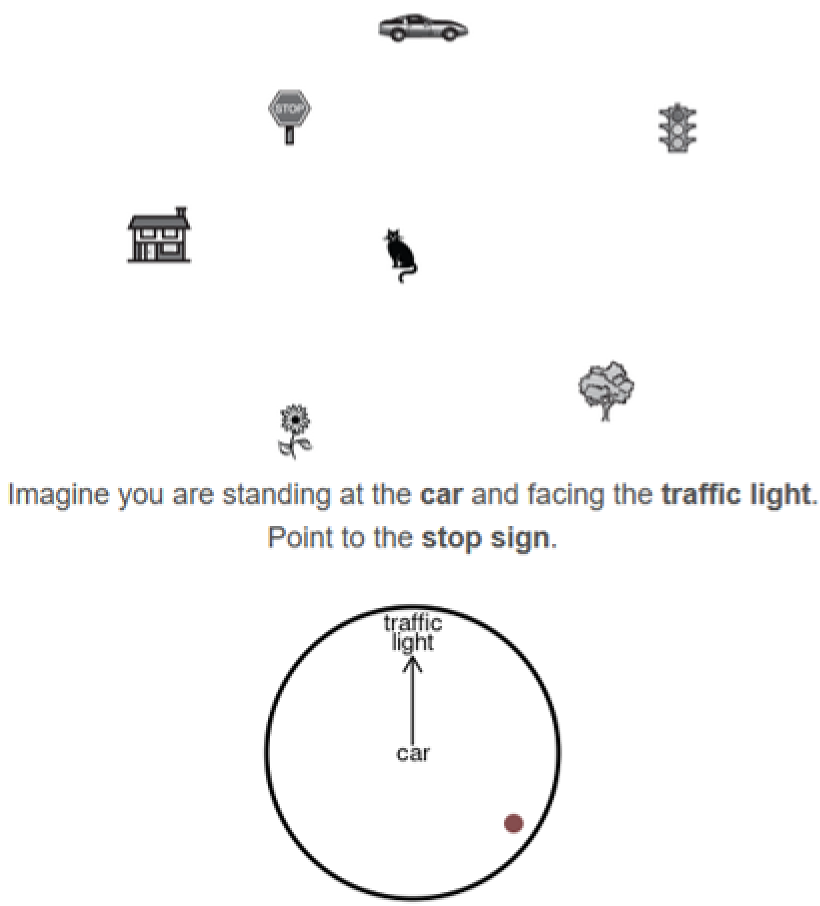
Note. Dots represent estimates of coefficients, and whiskers represent 95% confidence interval. **a)** For spatial perspective, extraversion was the only statistically significant predictor with no interaction effect of perspective. **b)** For social perspective (mentalizing), the overall model was not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

Figure B.10: Examples of the 3D perspective taking task.



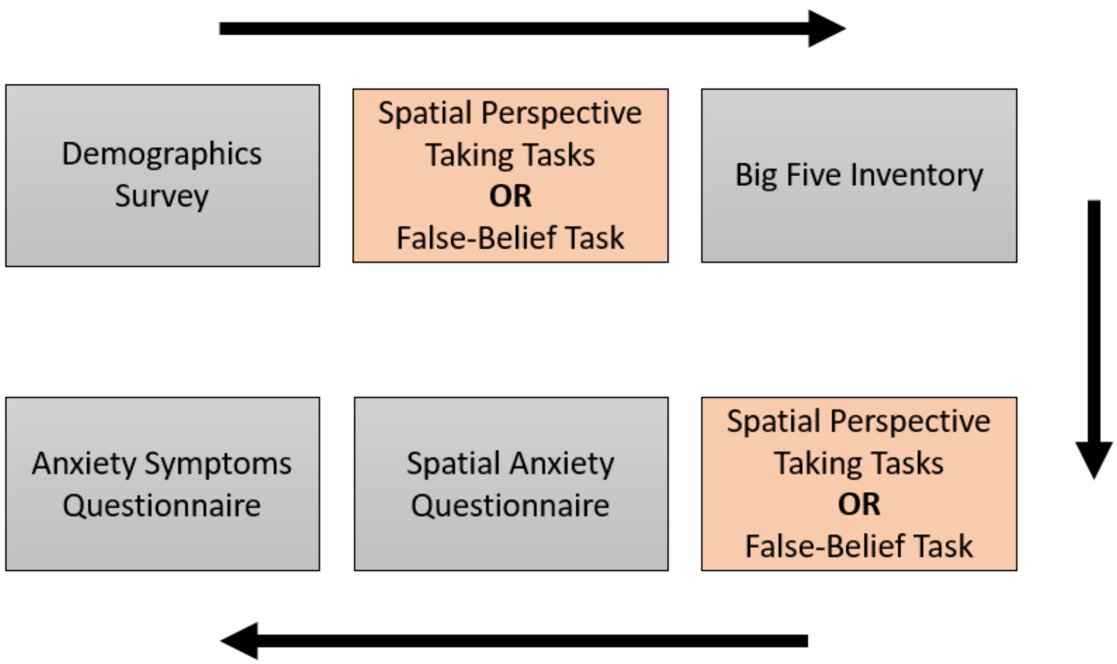
Note. The left figure depicts a trial where participants need to take their own perspective. The right figure depicts a trial where participants need to take the perspective of the head on the left side. Down the left-hand column, the correct answers are: front, left, and right. Down the right-hand column, the correct answers are: left, front, and right.

Figure B.11: Examples of the Spatial Orientation Task.



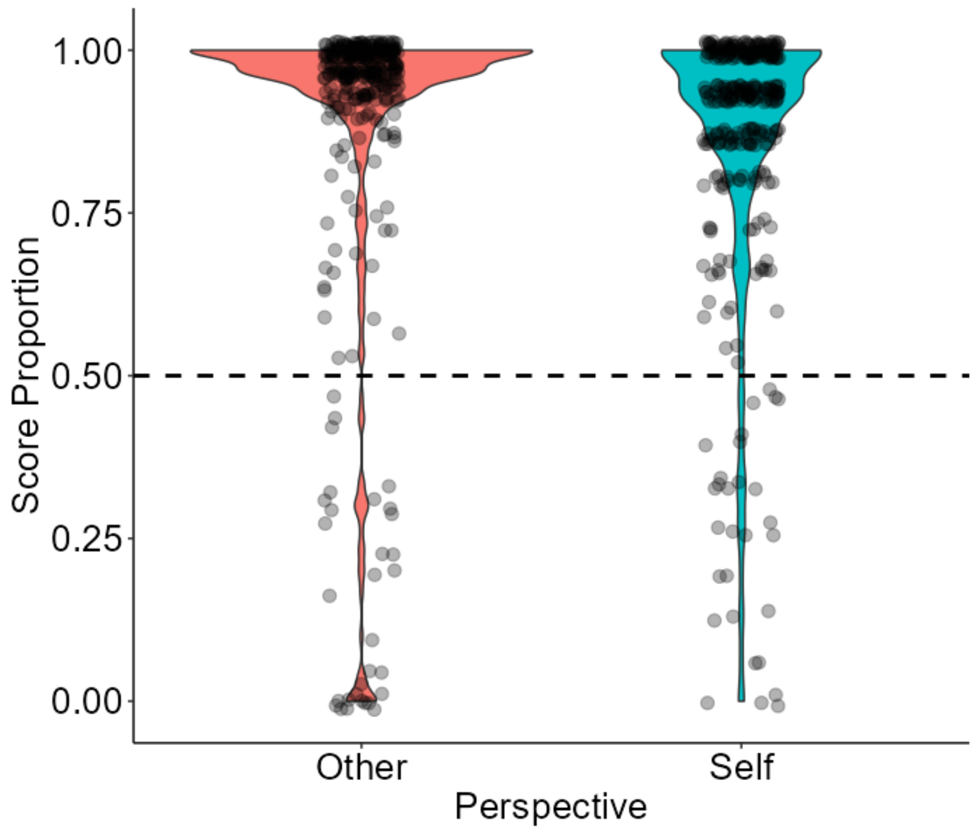
Note. The top image illustrates the layout of objects that remains constant throughout the task. The sentences in between the two images is the prompt the participants needs to imagine. The circular diagram below is where the participant must click where they imagine the target object is located. The red dot at the lower right side of the circular diagram is what the participant sees if they click on the diagram.

Figure B.12: Study 2: Procedure flow diagram.



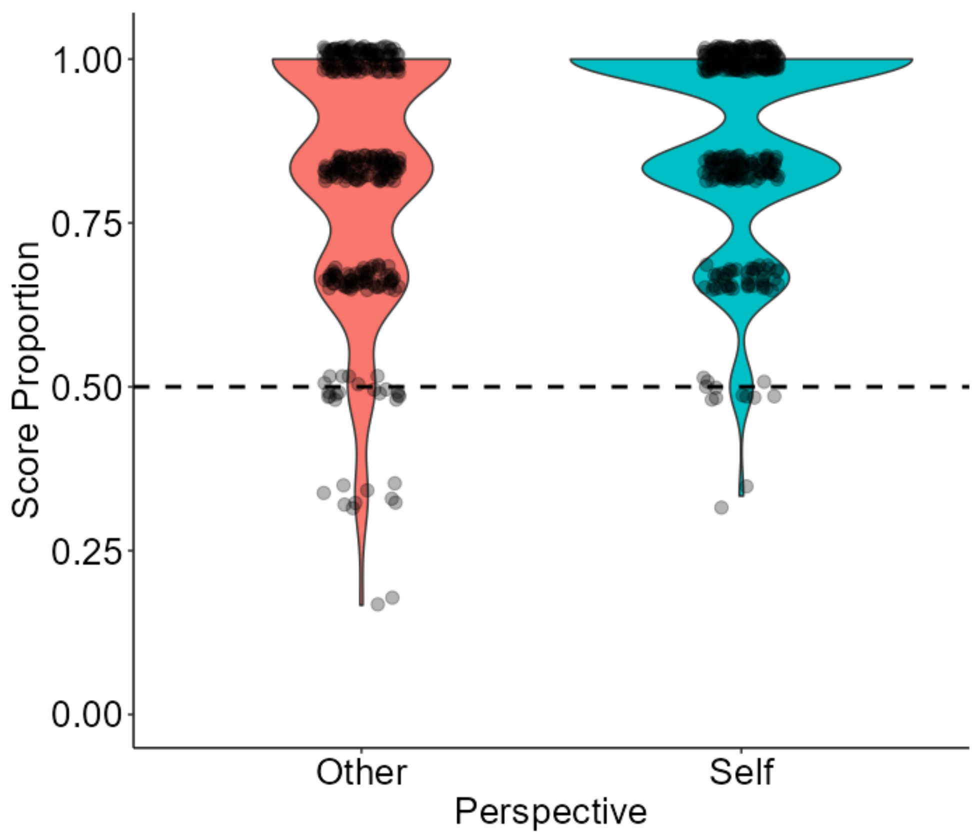
Note. The highlighted boxes describe randomized tasks. The second highlighted box assigns the task that was not assigned in the first highlighted box of the procedure. When spatial perspective tasks are assigned, participants will complete both the 3D perspective taking task and the Spatial orientation task in random order.

Figure B.13: Study 2: Violin Plots of 3D Perspective Taking Task.



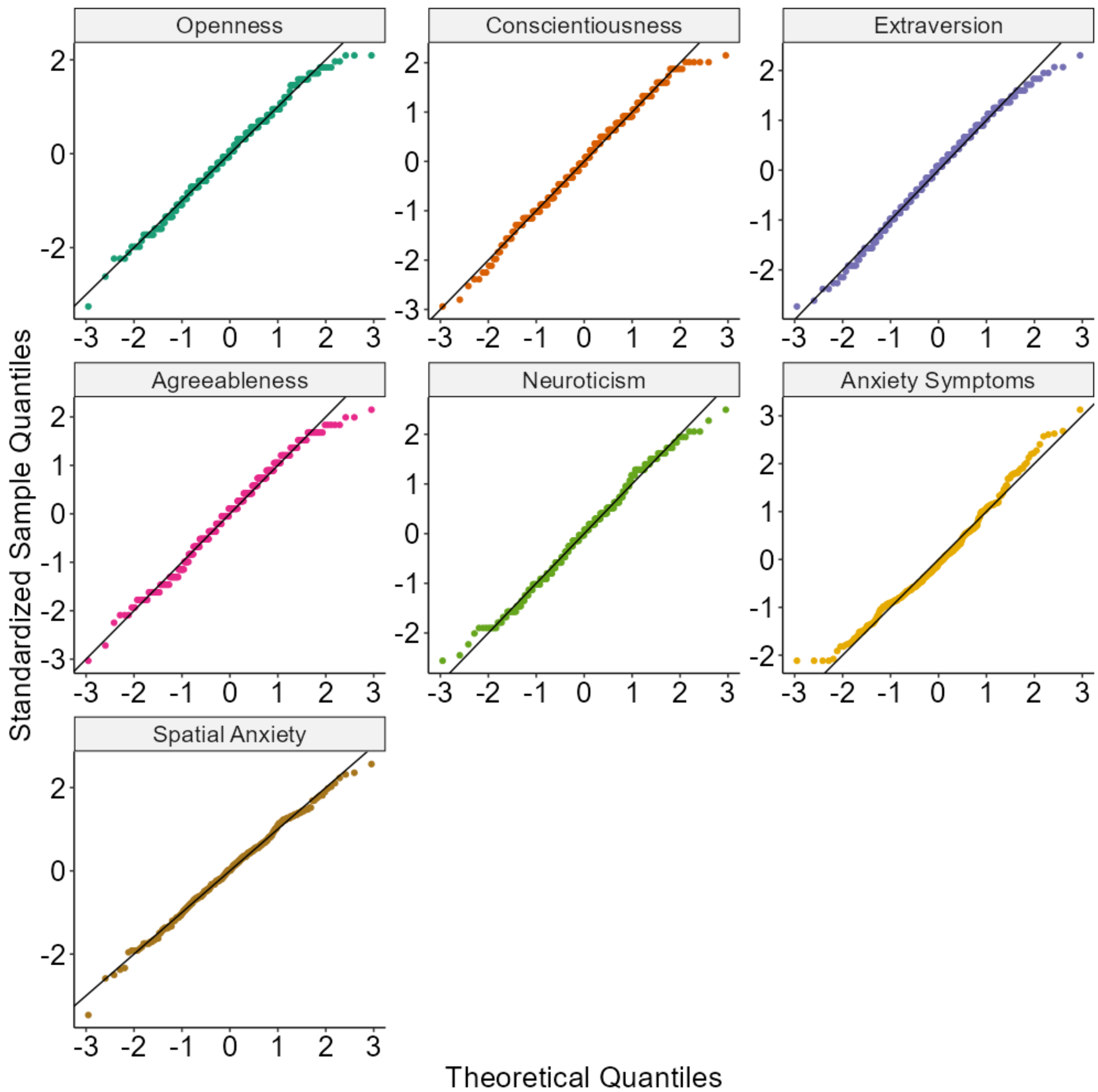
Note. Violin plots show ceiling effect for the 3D perspective taking tasks. Dashed-lines represent chance performances for the 3D perspective taking task at 0.5.

Figure B.14: Study 2: Violin Plots of Social Perspective Taking Task.



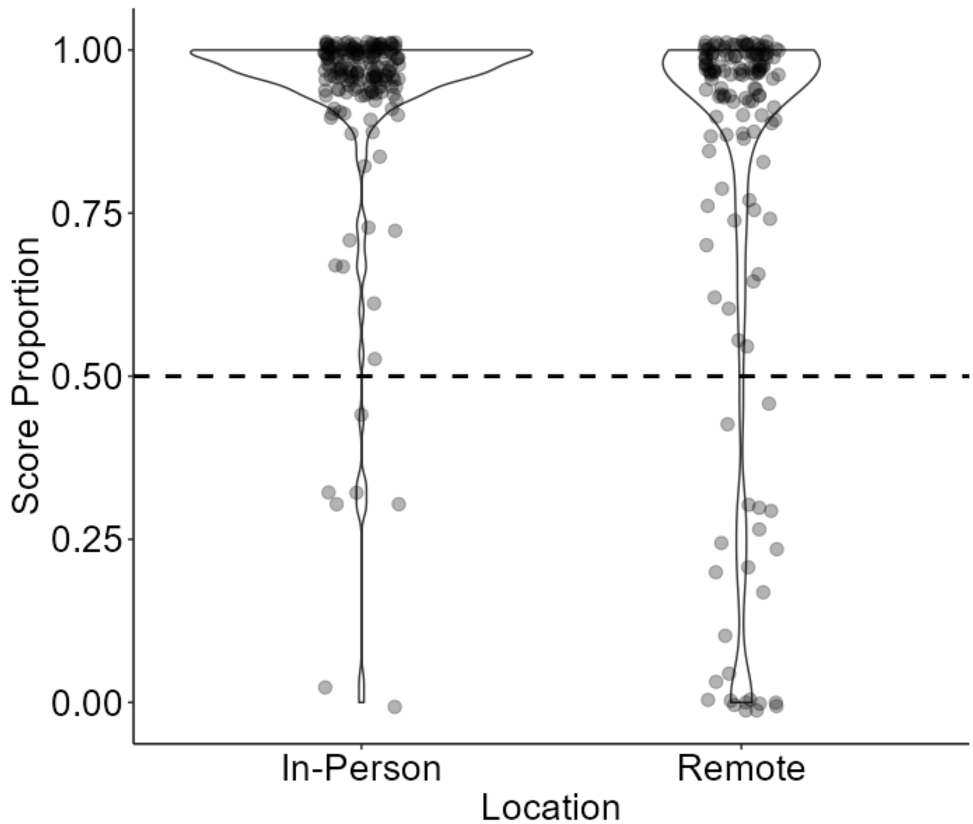
Note. Violin plots show ceiling effect for the social perspective taking tasks. Dashed-lines represent chance performances for the Social perspective taking task at 0.5.

Figure B.15: Study 2: QQ Plots of Individual Difference Factors.



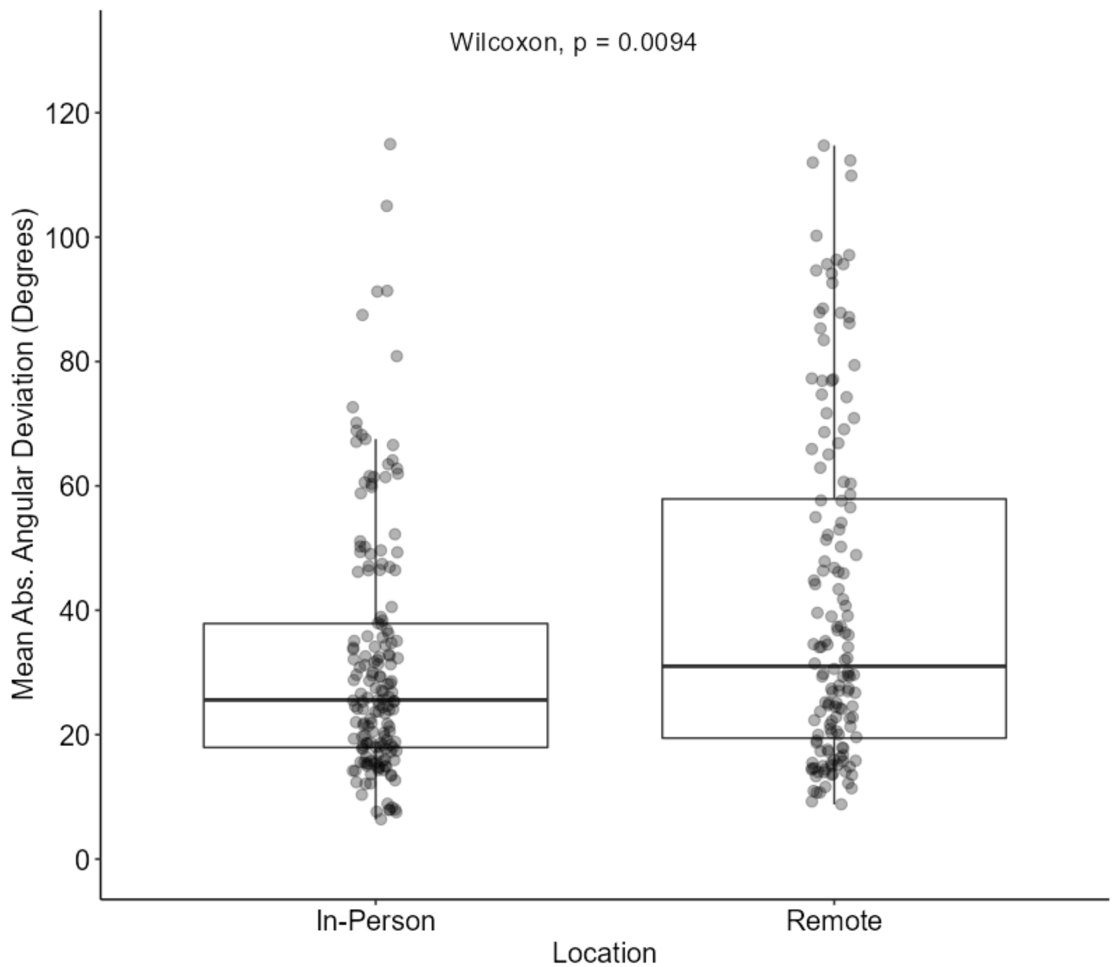
Note. Most variables had normally distributed samples. All variables showed very limited deviations towards the tails. I decided to consider all the distributions to be normal for analyses.

Figure B.16: Study 2: Violin Plots of the 3D Perspective Taking Task for "Other" Condition Between Location.



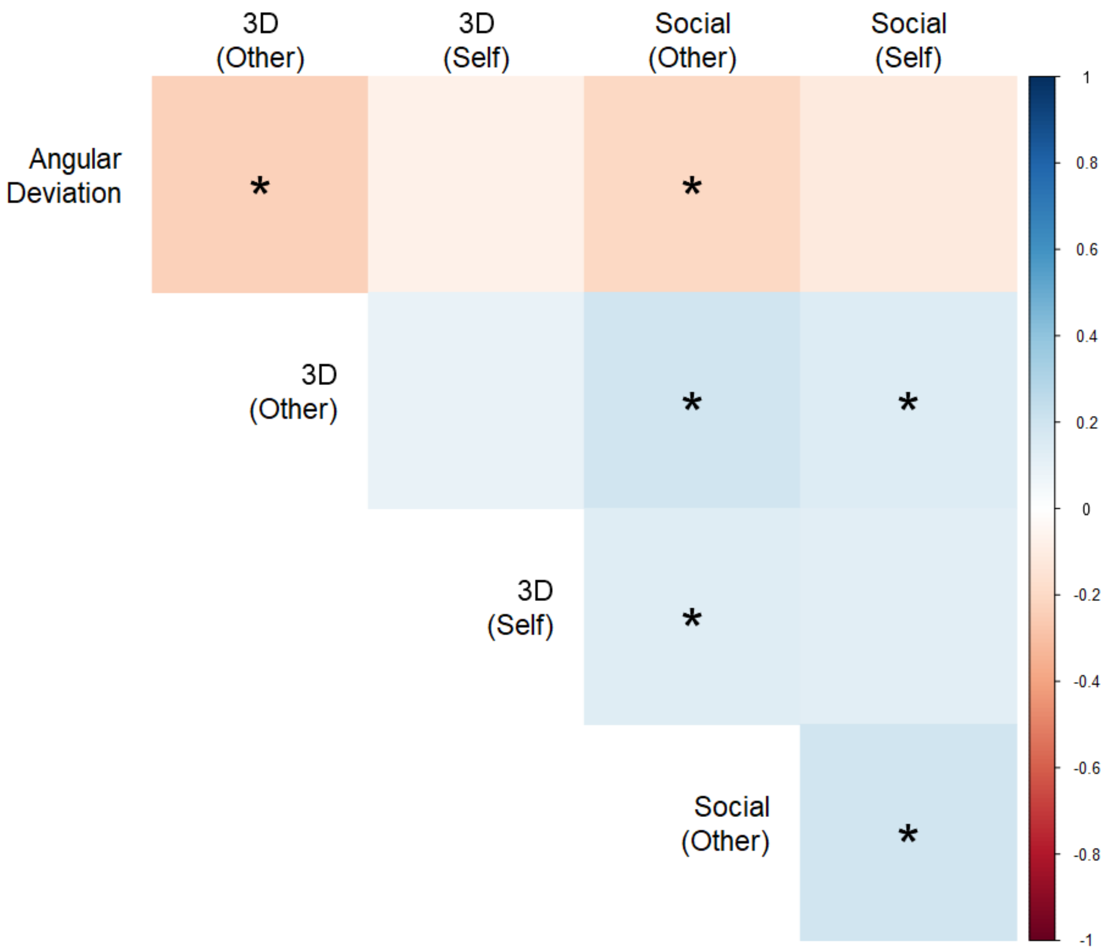
Note. Violin plots show the difference in proportion of scores between in-person and remote participants for the "Other" condition of the 3D perspective taking task. Dashed-lines represent chance performances for the 3D perspective taking task at 0.5.

Figure B.17: Study 2: Box Plots of the Spatial Orientation Task for Between Location.



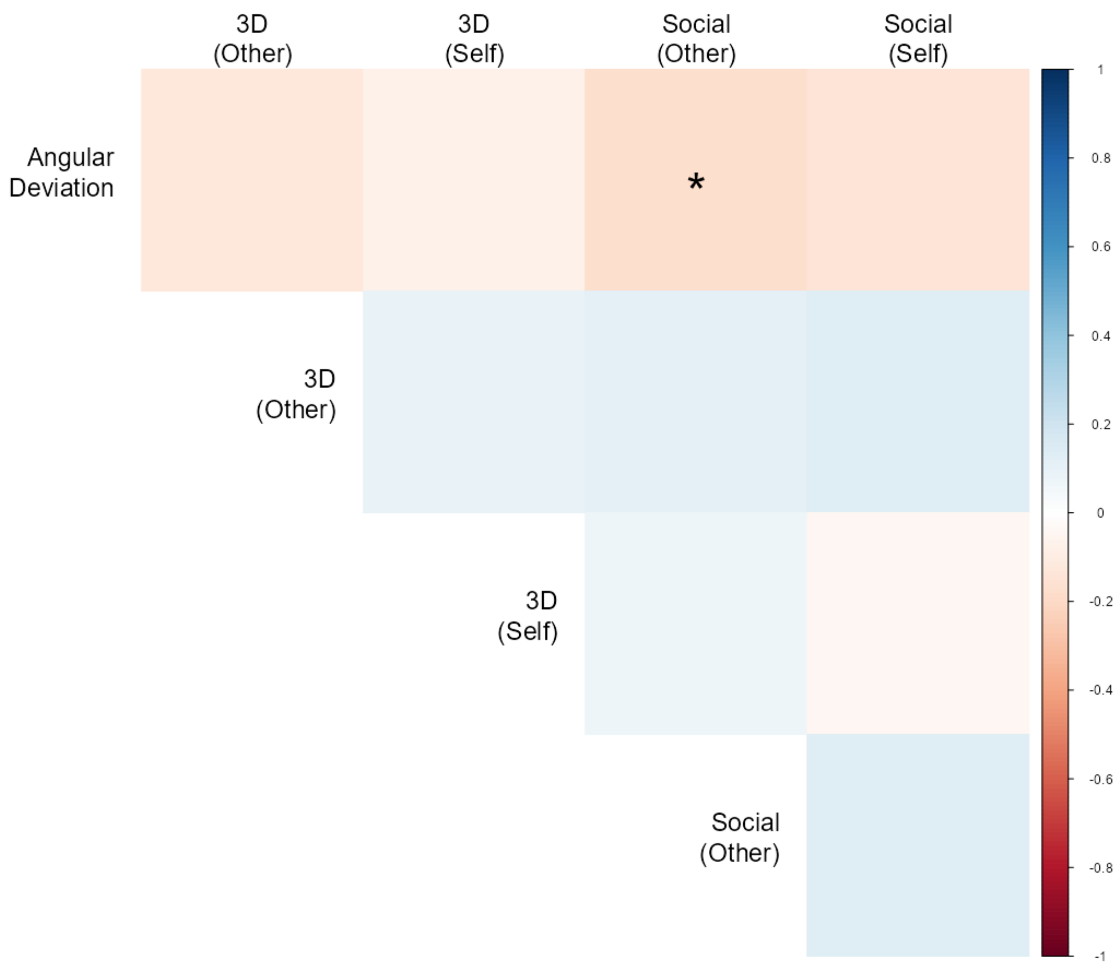
Note. Box plots show the difference in mean absolute angular deviation between in-person and remote participants. In-person participants tended to perform better with smaller mean absolute angular deviations.

Figure B.18: Study 2: Correlation matrix between 3D perspective task, spatial orientation task, and false-belief task.



Note. Correlation matrix of performance on the 3D perspective task (Spatial), and the false-belief task (Social) for both the ”self” and ”other” conditions, and spatial orientation task. Of note is the significant correlation between the “Other” spatial perspective taking score and the “Other” false-belief score and their negative correlation with angular deviation.
$*$ Represents significance at $\alpha = 0.005$ ($\alpha = 0.05$ with Bonferroni adjustment for 10 tests.)

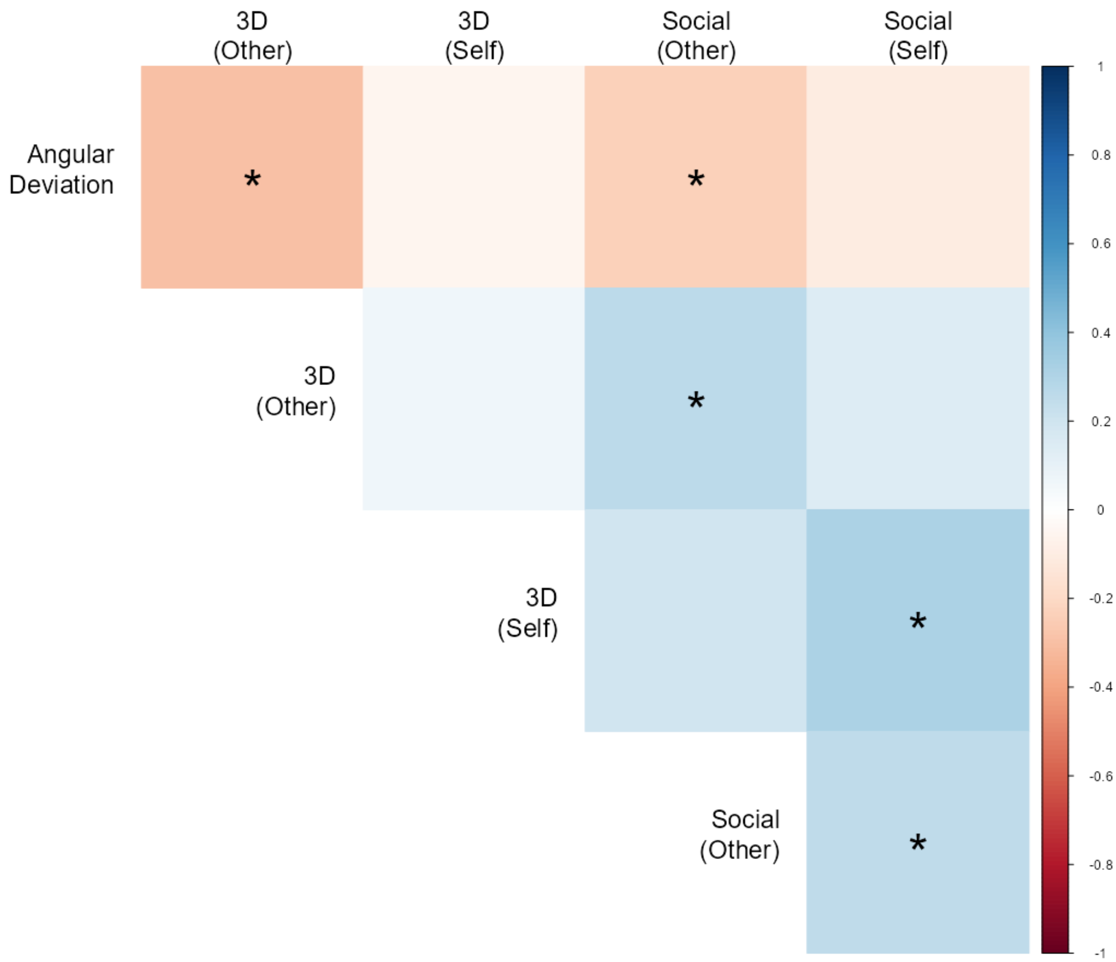
Figure B.19: Study 2: In-Person Participant Correlation Matrix.



Note. Correlation matrix of performance on the 3D perspective task (Spatial), and the false-belief task (Social) for both the ”self” and ”other” conditions, and spatial orientation task, for in-person participants. Of note is the sole significant negative correlation between the “Other” social perspective and angular deviation of the spatial orientation task. Unlike the cumulative correlation analysis, most of the significant correlations are no longer present. However, this result is consistent with the hypothesis that people who are better at taking other’s social perspective are also better and spatial perspective taking.

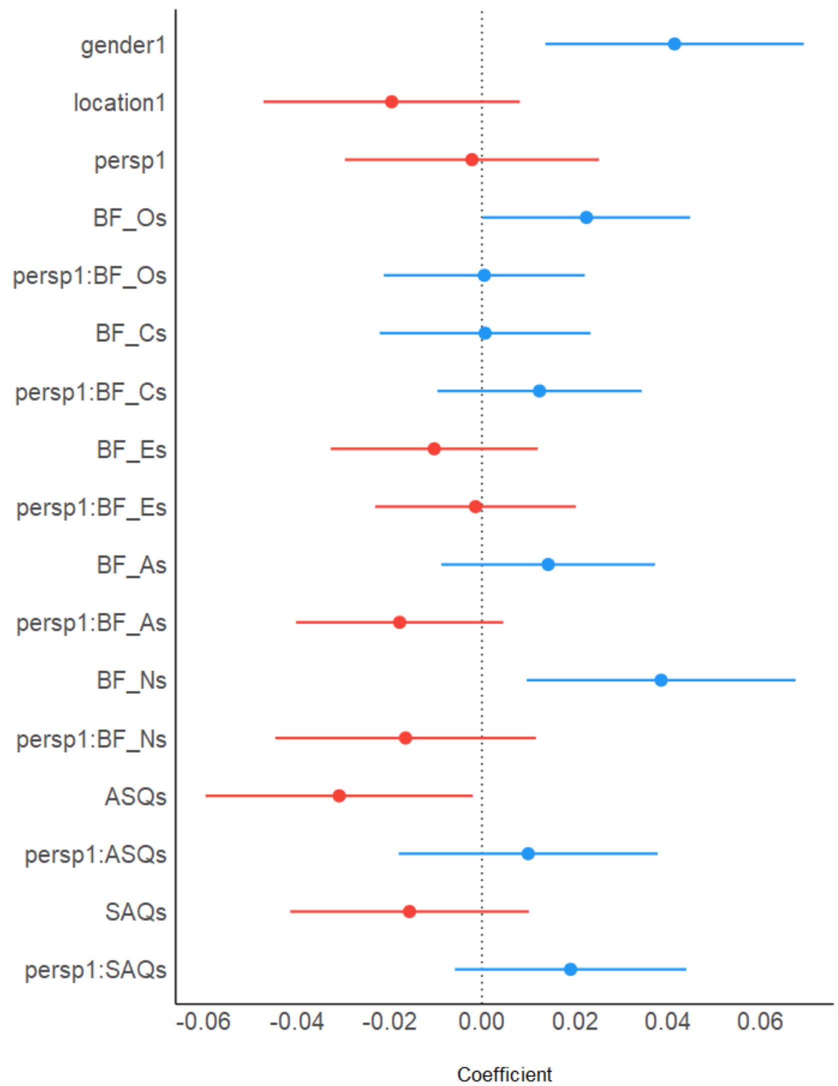
$*$ Represents significance at $\alpha = 0.005$ ($\alpha = 0.05$ with Bonferroni adjustment for 10 tests.)

Figure B.20: Study 2: Remote Participant Correlation Matrix.



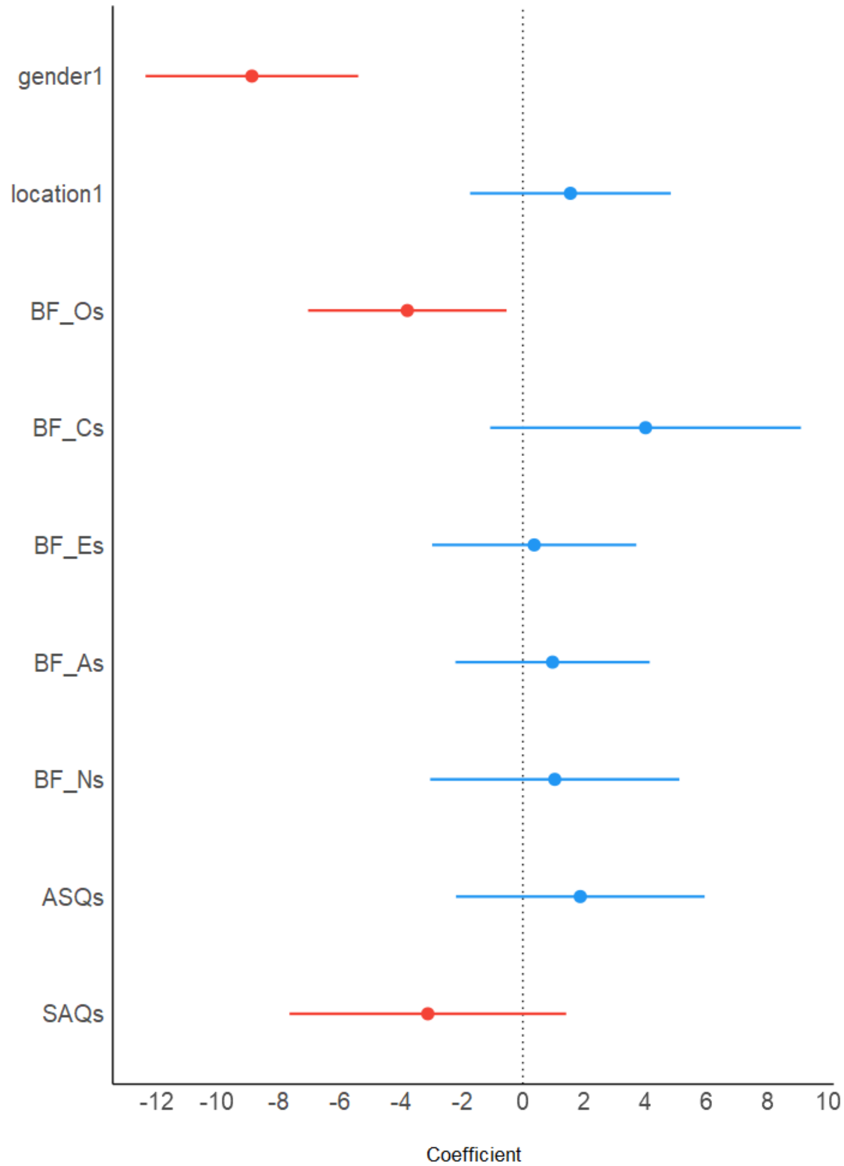
Note. Correlation matrix of performance on the 3D perspective task (Spatial), and the false-belief task (Social) for both the "self" and "other" conditions, and spatial orientation task, for remote participants. These results are consistent with the cumulative correlation analysis where there is a significant correlation between the "Other" condition of the 3D perspective task and the "Other" condition of the social perspective task.
$*$ Represents significance at $\alpha = 0.005$ ($\alpha = 0.05$ with Bonferroni adjustment for 10 tests.)

Figure B.21: Dot and whiskers plots of multiple regression analyses.



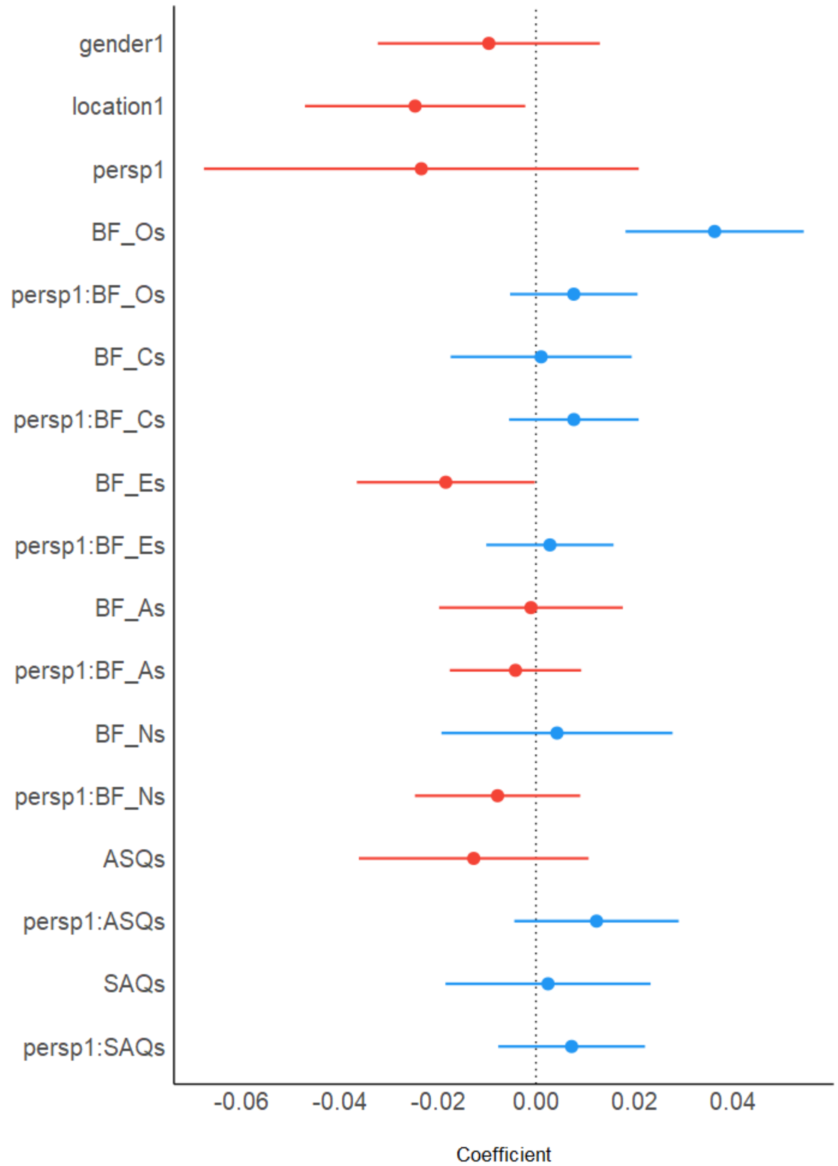
Note. Dots represent estimates of coefficients, and whiskers represent 95% confidence interval. Gender, openness, and negative emotionality were positive predictors of task performance. Anxiety symptom was a negative effect. There was no interaction effect of perspective.

Figure B.22: Dot and whiskers plots of multiple regression analyses.



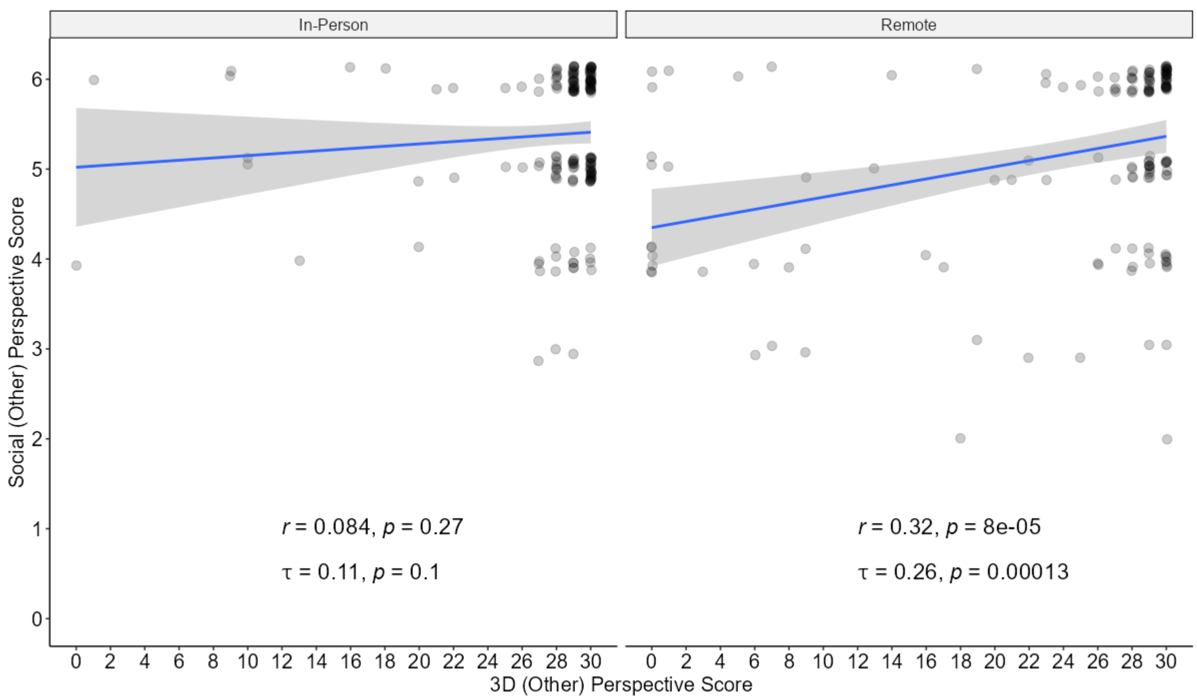
Note. Dots represent estimates of coefficients, and whiskers represent 95% confidence interval. Gender, and openness, positive predictors of task performance. There was no interaction effect of perspective.

Figure B.23: Dot and whiskers plots of multiple regression model of the false belief Task.



Note. Dots represent estimates of coefficients, and whiskers represent 95% confidence interval. Openness was a positive predictors of task performance, and extraversion was a negative predictor of task performance. There was no interaction effect of perspective.

Figure B.24: Study 2: Scatter Plots of “Other” Condition of 3D Perspective Task & False-Belief Task.



Note. This scatter plot depicts the difference in correlation between the “Other” condition of the 3D perspective taking task and that of the social perspective taking task (false-belief). There are more poorer responses in the remote condition, contributing to a stronger correlation.