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It's All About Perspective: An Examination of Spontaneous and Implicit / Explicit Visual Perspective-Taking in Turner Syndrome

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Abstract

The ability to take another person's perspective is a fundamental aspect of social cognition and an important contributor to social interaction. In this online research study, we explored potential differences in visual perspective-taking between adults with Turner Syndrome (TS) and neurotypical controls. TS participants were studied as they have been shown to struggle with visuo-spatial reasoning. Therefore, we were interested in whether this extended to problems with visual perspective-taking. In the first experiment, participants were presented with a series of questions measuring spontaneous responses to the actions of an actor in a visual scene. The proportion of *Self* and *Other* responses for each question were recorded. We found that TS participants provided significantly more *Other responses* than controls when the task instructions made explicit reference to the actions of the actor, but not when the perspective to adopt was ambiguous. In the second experiment, participants were presented with the image of a three-dimensional room and asked to verify the number of dots on the walls of the room, from either the perspective of an avatar or their own. We found no significant difference in the reaction times and accuracy of Turner Syndrome participants, compared to controls. Overall, these findings demonstrate that both spontaneous and non-spontaneous visual perspective-taking is not impaired in Turner Syndrome.

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1 Introduction

Social competence and understanding the mental states of others requires taking an alternative visual perspective. Often it involves ignoring one's own (egocentric) perspective to better understand the thoughts, actions, and (allocentric) perspective of other individuals (Erle & Topolinski, 2017). This is believed to be a fundamental aspect of social cognition and higher-order processes, such as mentalising (Martin et al., 2019). Different spatial perspectives can be taken either consciously or unconsciously, automatically or spontaneously, depending on the task (Van der Graaff et al., 2014). Previous research shows that inhibiting an egocentric perspective and shifting to an allocentric one is an effortful process, dependent on the extent of one's executive function (EF) (Brunsdon, Bradford & Ferguson, 2017). EF describes a range of neurocognitive processes that are necessary for emotional regulation, social functioning, and mundane actions when in a dynamic social environment (Zelazo, 2020).

One skill associated with EF is inhibitory control, which has been shown to account for a significant amount of variance in the performance of neurotypical adults during perspective-taking tasks (Li et al., 2021). Executive dysfunction has also been demonstrated in those with autism-spectrum disorder (ASD). For example, many studies have observed deficits in cognitive flexibility, planning, and working memory (Demetriou et al., 2018; Johnston et al., 2019; Wang et al., 2017). According to neuroimaging research, these deficits may reflect structural and / or functional differences in the prefrontal cortex of ASD patients, compared to controls (Gilbert et al., 2009; Luna et al., 2002). Additional Research has demonstrated executive dysfunction in those with a traumatic brain injury (TBI). Nadebaum, Anderson and Catroppa (2007) showed impaired cognitive flexibility and reasoning, in those with severe TBI. However, those with a mild-moderate TBI had relatively spared EF

(Nadebaum et al., 2007). Furthermore, Anderson and Catroppa (2005) found that children with a severe TBI exhibited the greatest recovery of EF over 24 months, in comparison to age-matched children with a less severe TBI. This suggests that EF deficits are recoverable in the long-term but the extent of that recovery is dependent on the severity of the TBI and age at injury, at least for children (Anderson & Catroppa, 2005).

There is evidence to suggest that those with the female genetic disorder Turner Syndrome (TS) possess more severe executive dysfunction than neurotypical adults. Typical EF deficits in TS include behavioual planning, inhibitory control, and cognitive flexibility (Mauger et al., 2018; Hutaff-Lee et al., 2019). All these executive processes are associated with visual perspective-taking (VPT) to a variable extent. Therefore, we might expect those with TS to show greater difficulties with VPT than controls.

In what follows, mentalising (also known as 'theory of mind') is discussed first, followed by a detailed analysis of VPT in both TS women and neurotypical adults. Finally, the clinical and neurological characteristics of TS are considered.

1.1 Mentalising

Mentalising is a higher-order social-cognitive process that has been studied extensively in neurotypical adults (Xu, 2021; Dimić & Krstić, 2020) as well as clinical populations, including autism-spectrum disorder (Andreou & Skrimpa, 2020; Jones et al., 2018) and attention-deficit-hyperactivity-disorder (Pineda-Alhucema et al., 2018; Tesfaye & Gruber, 2017). Mentalising refers to the ability to infer and interpret the beliefs, emotions and intentions of others, which subsequently allows us to predict other people's behavior (Apperly, 2012; Wang et al., 2009). This is thought to play a role in the acquisition of knowledge associated with social norms and expectations, which helps drive everyday behavior (Nguyen & Gonzalez, 2021).

One common task that is used to measure mentalising in both neurotypical and clinical populations of children is the Sally-Anne Task (SAT) (Baron-Cohen, Leslie & Frith, 1985). The SAT is a 'false belief task', as it requires participants to distinguish between their own true belief and someone else's (false) belief of a real word event / action (Dennet, 1978; Baron-Cohen, 2001). Previous research has demonstrated that neurotypical children four years old and over generally pass the SAT, and this may be an important milestone for mentalising abilities (Girli & Tekin, 2010; Wu & Schulz, 2021; Saeedi et al., 2014).

Improvements in EF throughout normative development are intimately tied to advancements in mentalising (Pellicano, 2007). For example, numerous research studies have demonstrated a robust correlation between performance in false-belief tasks (a common measure of mentalising) and individual differences in EF (Carlson, Moses & Claxton, 2004; Carlson & Moses, 2001; Pellicano, 2007). One meta-analysis by Perner and Lang (1999) reported a significant correlation between EF and mentalising across a range of studies, whereby improvements in one translated to advancements in another. More specifically, research has demonstrated significant relations between certain aspects of EF such as cognitive flexibility (Frye, Zelazo & Palfai, 1995), inhibitory control (Carlson, Moses & Breton, 2002) and mentalising. One explanation is that mentalising has a substantial executive component (Pellicano, 2007), potentially to suppress a natural response tendency during mentalising tasks (Hughes & Russell, 1993). If TS participants have dysfunctional executive processes, we would expect this to be reflected in the results obtained from measures of mentalising (Hong, Scaletta-Kent & Kesler, 2009).

Research shows that TS patients have impaired mentalising abililties, specifically the interpretation of other people's emotions (Hong, Scaletta-Kent & Kesler, 2009). For instance, Lawrence et al. 2003 presented TS patients with a range of photographs showing only the upper half of someone's face and eye region. Results showed that those with TS were significantly less accurate in assigning emotional labels to visual cues from the upper half of a face, particularly for fearful and angry facial expressions. Further research has found that TS participants, including children (Davenport et al., 2020) and adults (Shi et al., 2016) have abnormally enlarged amygdalae, as well as aberrant connectivity between the amygdalae and fusiform gyrus (Skuse, Morris & Dolan, 2005; Hong et al., 2014). This is important as these regions are implicated in encoding the social salience of emotional stimuli (Hong, Scaletta-Kent & Kesler, 2009; Geckeler, Barch & Karcher, 2022), including facial expressions (Framorando et al., 2021). Therefore, it is possible that this may at least partially explain why those with TS struggle with affect interpretation.

The deficits in visuo-spatial reasoning in those with TS, such as visuo-spatial WM, may also contribute to impairments in mentalising (Hart et al., 2006; Reimann et al., 2020). Dysfunctional spatial WM processes may reduce one's ability to correctly interpret nonverbal cues – such as facial expressions and body language (Hong et al., 2009). For example, a number of studies show that body language assists in the interpretation of beliefs, emotions, and intentions of other people (Mitchell & Phillips, 2015; Smith & LaFreniere, 2009; Rizzolatti & Craighero, 2004). Similarly, research has demonstrated poor EF in TS compared to neurotypical adults (Lepage et al., 2013; Mauger et al., 2018; Tamm, Menon & Reiss, 2003). Some researchers suggest this may explain why those with TS find it more challenging to recognise that another visual-perspective exists (Hong et al., 2009).

1.2 Visual perspective-taking

VPT is the ability to understand that the contents of one's own visual (or non-visual) field can be viewed from both the viewpoint of oneself (egocentric) as well as from another individual (allocentric) (Martin et al., 2019). Both implicit (Doi et al., 2020) and explicit (Schwarzkopf et al., 2014; Zhai et al., 2021) levels of VPT have been proposed (Apperly &

Butterfill, 2009). Implicit VPT refers to the rapid and automatic representation of another person's perspective. The effects associated with implicit perspective-taking can be observed when interference from another's perspective interferes with the perspective of oneself. An explicit VPT effect is observed when participants are forced to shift between the perspective of the self and that of an actor's for an equivalent visual scene (Martin et al., 2019). Explicit VPT is typically slower as it requires more computation of the visual scene than the implicit level. Therefore, explicit VPT may not fully mature until adulthood (Martin et al., 2019).

1.2.1 Visual perspective-taking level one

Level one VPT (Flavell et al., 1981) refers to the ability to recognise whether something present in the visual field is visible to another person, but not how it looks, and involves using line-of-sight judgements from the perspective of oneself (Martin et al., 2019). The skills associated with this level of VPT are thought to mature by the age of 24-months (Moll & Tomasello, 2006) and has been demonstrated by non-human animals such as primates (Arre, Stumph & Santos, 2021) and species more evolutionarily distant to humans, such as birds (Emery & Clayton, 2004).

Samson et al. (2010) investigated level one VPT in a group of neurotypical adults using a newly developed visual-perspective paradigm. The paradigm referred to as the 'dot perspective task' involved presenting participants with the image of a three-dimensional room consisting of two lateral walls, a rear wall and a human avatar standing in the center of the room gazing left or right. 0-3 red-coloured dots were displayed on either the left wall, right wall or both. For instance, one dot could be on the left wall and two on the right Alternatively, there may be none on the left and three on the right. Participants were asked to verify the number of dots from either their own perspective (*Self*) or that of the avatar's (*Other*), whilst ignoring the irrelevant perspective (Samson et al., 2010). In half of the experimental trials, the avatar saw the same number of coloured dots as the participant (*Consistent* trials) whereas in the remaining trials the avatar saw a different number of dots (*Inconsistent* trials). They discovered that errors and reaction time (RT) were significantly greater for *Inconsistent* trials, both when participants were asked to verify the avatar's perspective (known as egocentric intrusions) and when they had to report their own perspective (altercentric intrusions). This suggests that another individual's perspective can interfere with making explicit judgements about our own and vice-versa (Samson et al., 2010). Altercentric intrusions have been reported in both children and adults, which suggests that the ability to take an alternative perspective may be the result of a cognitively efficient process present from infancy (Surtees & Apperly, 2012).

It should be noted, however, that the effect of consistency reported by Samson et al. (2010) has been challenged for not measuring perspective-taking and theory of mind, but rather domain-general processes that do not involve the computation of mental states (Heyes, 2014; Cole & Millett, 2019). For example, the directionality of the avatar's facial features (forehead, eyes, nose etc) and gaze automatically shift attention to one side of the scene and subsequently enhances processing of the dots on inconsistent trials (Santiesteban et al., 2014). Moreover, comparable consistency effects have been reported when the avatar is replaced with stimuli that is known to direct attention but not possess mental states, including arrow stimuli (Kingstone et al., 2004; Santiesteban et al., 2014) and cameras (Wilson et al., 2017).

While some have argued that these consistency effects can be explained *solely* by domain-general attentional effects (Cole et al., 2016), Samson et al. (2010) discuss attentional cueing as a process that *contributes* to VPT and it is with this conception in mind that the task is used in this thesis.

Both older (Clements & Perner, 1994) and more recent (Schneider, Slaughter & Dux, 2017) research supports the notion that humans have two distinct systems for mentalising.

One is implicit, automatic and matures relatively early in one's lifespan (~24-months (Call & Tomasello, 2011)) whereas the other is explicit, slower and fully develops later on during adulthood (Apperly & Butterfill, 2009). Level one VPT requires less cognitive control and processing than level two, meaning that level one may be computed by a faster, implicit system for mentalising. However, some studies have obtained evidence against implicit mentalising and instead argued for the importance of 'sub-mentalising', whereby generic memory and attentional processes produce altercentric interference (Heyes, 2014; Santiesteban et al., 2014).

Santiesteban et al. (2014) adapted Samson et al's. (2010) VPT paradigm to test whether altercentric interference relies on implicit or sub-mentalising processes. Rather than a human avatar placed centrally in a 3D room, they used arrow stimuli oriented towards one of two lateral walls. They found that participants were slower to report the number of coloured dots when this number was different to a number that the arrow was pointing to. As arrows are more directional than agentive in nature and rely on attentional processes, these results have been interpreted as evidence for the importance of sub-mentalising rather than implicit mentalising in VPT (Santiesteban et al., 2014).

Furlanetto et al. (2016) adapted Samson et al's. (2010) paradigm so that the avatar was wearing mirrored-lensed goggles in two different colours. Using a belief induction protocol, participants were led to believe that one colour meant the avatar could see the dots ('seeing' condition) whereas if they were wearing goggles with the other colour then they could not ('non-seeing' condition). They argued that should sub-mentalising be wholly sufficient to account for altercentric intrusions, they should be observed in both conditions. However, they discovered that only the 'seeing' condition triggered altercentric intrusion effects, which is evidence for the role of implicit mentalising over sub-mentalising in the paradigm designed by Samson et al. (2010).

Additional research has distinguished between 'perspective-calculation' and 'perspective-selection' in relation to the demands of a VPT task (e.g. Ramsey et al., 2013; Samson et al., 2010), with perspective-calculation likely the result of implicit mentalising (Surtees & Apperly, 2012; Conway et al., 2017) and perspective-selection the result of EF (Ramsey et al., 2013). Qureshi, Apperly and Samson (2010) presented participants with the Samson et al., (2010) paradigm which they completed alongside a secondary task (incongruent finger-tapping in response to auditory stimuli) to increase the demand on executive resources. They found that administering an effortful secondary task had no significant effect on taking the *Self* or *Other* perspective. On the contrary, slower RT's were observed when participants had to 'select' which of the perspectives to use for a given trial. Collectively, these results suggest that perspective-calculation is automatic whereas the decision-making involved in perspective-selection are dependent on executive processes. As impaired EF has been reported in TS patients across a range of tasks (Lepage et al., 2013; Mauger et al., 2018; Tamm et al., 2003), TS participants should show a greater perspective-selection difficulty across level one VPT tasks. If this were true, we would expect TS participants to make more errors than controls when asked to shift between perspectives in the Samson et al. (2010) paradigm.

1.2.2 Visual perspective-taking level two

Level two VPT (Flavell et al., 1981) is the ability to judge *how* something is perceived from an alternative perspective (Martin et al., 2019). The simplest way to measure the extent of someone's level two VPT ability is to ask laterality questions, which require participants to report the presence of objects on the left and / or right-hand side of the visual field (Kessler & Rutherford, 2010; Michelon & Zacks, 2006; Martin et al., 2019). Examples include "does the actor see more objects on their right-hand side or left-hand side?" and "on what side of the desk does the actor place the object?”. It is believed that to answer laterality questions quickly and accurately, participants must perform a ‘mental rotation’ of their own perspective into the location of the actor (the allocentric perspective location, (Surtees, Apperly & Samson, 2013; Wang et al., 2015; Martin et al., 2019).

Tversky and Hard (2009) investigated spontaneous level two VPT in neurotypical adults. They presented participants with a photograph of an actor seated at a desk looking or reaching for one of two objects. Participants were asked to describe the spatial relationship between the two objects. It was discovered that when the actor was reaching for one of the objects, 30% of the participants spontaneously described the relationship from the allocentric point-of-view. When the actor merely looked at one of the objects, the proportion of allocentric responses was 21% (Tversky and Hard, 2009). Moreover, the researchers discovered that phrasing a question in terms of an action triggered significantly more allocentric responses (~52%) than static questions (~32%) that made no reference to an action, independent of whether an actor was mentioned in the question. These findings suggest that spontaneous VPT responses can be triggered by seeing someone else perform an action and potentially interpreting an actor playing a key role in an interaction with an object. The results may even have implications for mentalising, as taking someone else’s visual perspective may allow for greater understanding of their future actions and / or behavioral intentions during social interactions (Tversky & Hard, 2009).

Quesque, Chabanat and Rossetti, (2018) asked participants to either identify or localize ambiguous stimuli, such as a human actor in a visual scene. They found that the mere presence of an actor led to significantly more allocentric responses. Furthermore, by blindfolding the actor, they found that participants still endorsed the perspective of the actor even though they were completely irrelevant to the context. According to Quesque, Chabanat and Rossetti, (2018) this challenges the idea that action affordances (all the potential action possibilities for any given object) result in greater allocentric VPT responses, as demonstrated by Tversky and Hard (2009). Lastly, they demonstrated that in the absence of an actor in the visual scene, many participants still spontaneously endorsed the allocentric perspective as if the actor was present (Quesque, Chabanat & Rossetti, 2018). Overall, these results indicate that when interpreting ambiguous visuo-spatial stimuli, humans may possess a natural disposition to spontaneously take the perspective of another individual or location, even if they are irrelevant to the social context.

1.3 Neurological basis of TS

TS is a genetic disorder which occurs in ~1:2500 live female births and is characterised by the partial or complete absence of the second sex (*X*) chromosome. TS can occur with or without mosaicism (i.e. *some* cells of the offspring are missing an X chromosome or *all* cells are, respectively). The physical phenotype of TS includes short stature, webbing of the neck, hypogonadism (reduced estrogen secretion from the ovaries), cardiac defects as well as renal and endocrine abnormalities (World Health Organization, 1992). Additionally, young girls with TS report more issues forming and maintaining social relationships with their peers and often show impaired social competence (Lepage et al., 2013; Baker et al., 2020). Although there is significant heterogeneity in the physical and psychosocial symptoms of TS (Hutaff-Lee et al., 2019), there is a consistently reported profile of cognitive deficits, notably visuo-spatial WM (Kesler, 2007; Reimann, et al., 2020), inhibitory control, cognitive flexibility (Lepage et al., 2013) and processing speed (Hutaff-Lee et al., 2019). For example, Reimann et al. (2020) evaluated 142 participants with TS, including both children and adults. They found that those with TS scored significantly lower on a visuo-spatial WM task than controls. All of the above processes are involved in VPT and tasks that require participants to quickly shift between different perspectives (e.g. Samson, et al., 2010).

These cognitive deficits reflect structural and / or functional dysfunction in higher-order executive control regions, as has been demonstrated by neuroimaging. For example, structural imaging studies have consistently demonstrated reduced gray matter volume in the hippocampus (Brown et al., 2004), prefrontal cortex (Marzelli et al., 2011; Davenport et al., 2020) and bilateral parietal-occipital regions (Brown et al., 2002; Mullaney & Murphy, 2009) in TS participants. Functional neuroimaging research, including positron-emission tomography (PET) and functional magnetic resonance imaging (fMRI), have discovered significantly less activation in the parietal-occipital and temporal regions of TS participants compared to neurotypical controls. Hypoactivation in these areas is associated with increasingly pronounced deficits in visuo-spatial reasoning (Mullaney & Murphy, 2009). Studies specifically using fMRI have demonstrated reduced blood flow in the dorsolateral prefrontal cortex (Habe-Recht et al., 2001) and frontoparietal regions (Hart et al., 2006) which might help explain the EF deficits frequently reported in TS (Mullaney & Murphy, 2009).

1.4 Aims and hypotheses

Pre-existing TS research has found impaired visuo-spatial WM (Mazzocco, 2006; Beaton et al., 2010; Hutaff-Lee, 2019), executive dysfunction (Martin et al., 2016; Mauger et al., 2018), slower processing speed of spatial stimuli (Kesler et al., 2004; Temple, 2002) and reduced sustained attention (Green et al., 2015; Russel et al., 2006) in those diagnosed with TS. To the best of our knowledge, no research study has explored VPT in those with TS. Therefore, the aim of the present study was to investigate whether there were any differences in VPT between women diagnosed with TS and controls.

We explored VPT across two experiments. In the first experiment, we used a similar methodology as Tverksy and Hard (2009). As deficits in mentalising, visuo-spatial reasoning and specific aspects of EF have been reported (Hart et al., 2006; Reimann, et al., 2020; Lepage et al., 2013; Mullaney & Murphy, 2009), it was hypothesised that TS participants would give fewer spontaneous *Other* responses than the control group. Experiment 2 adapted the paradigm designed by Samson et al. (2010). Like Experiment 1, it was hypothesised that TS participants would make significantly more errors and take longer to take a perspective compared to the control group. For control participants, we expected to replicate the findings reported by Samson et al. (2010).

2 Method for Experiment One

2.1 Participants

A total of 65 female adults completed the experiment, including 24 TS participants and 41 neurotypical controls. An independent t-test showed no significant difference in the mean age between the TS group (M = 33, SD = 12) and control group (M = 37, SD = 14), $t(63) = -1.11$, $p = .273$. Furthermore, all participants had normal or corrected-to-normal vision. We did not test for handedness and we did not ask TS participants for proof of diagnosis from a certified medial professional. All TS participants were recruited from social media support groups (e.g. Facebook and Twitter via a message posted on the site) and the UK National Turner Syndrome Society. The control group consisted of both undergraduate students recruited using the University of Hull research participation system (RPS), as well as friends and extended family members of the principal researcher. In return for their time, those in the TS group were compensated with an Amazon.uk voucher (equal to the sum of 8.00 GPB) and those in the control group were given the option of receiving a voucher (4.00 GPB) or course credit. Ethical approval for the study was obtained in January 2022 from the University of Hull Faculty of Health Sciences Ethics Committee (see **Appendix A**).

2.2 Stimuli

As this was an online study, all participants completed the study using a personal laptop or desktop PC. Qualtrics (Qualtrics, Provo, UT) was used to present the stimuli and record participant responses. The stimuli consisted of eight photographs presented in colour and were approximately measured 700 x 600 pixels when displayed on the screen. Four of the photographs showed a female human model (actor) sat behind a desk where she either gazed directly in front or interacted with an object placed on the desk. The remaining four photographs showed a range of different everyday objects on the desk. Only three photographs were used to measure spontaneous VPT - this included two test questions (‘*what number is on the table?*’, ‘*where on the table does she place her book?*’) and one baseline question (‘*where on the table is the sponge?*’) (see Figure 1). The baseline question was associated with a photograph whereby the female actor was absent from the visual scene, participants were required to make an object laterality judgement in the absence of the actor. The remaining five photographs were ‘fillers’ that were presented randomly to make it less likely that participants would realise the task was about VPT, thus ensuring more spontaneous responses.

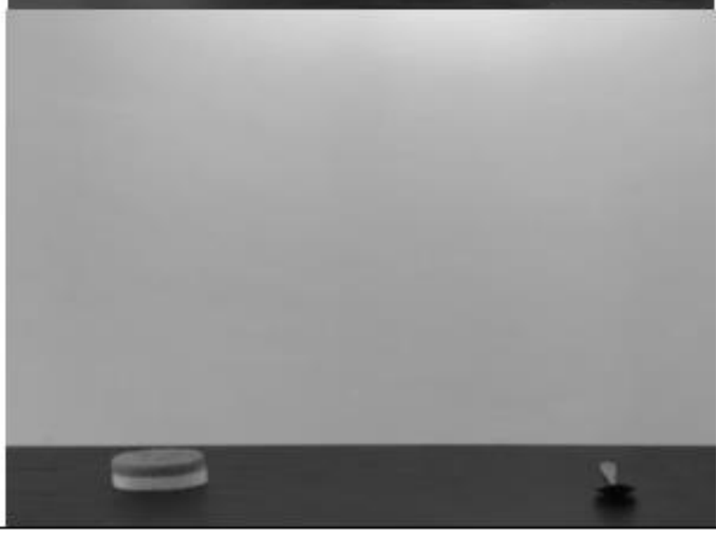
Question	Image
What number is on the table?	
Where on the table does she place her book?	
Where on the table is the sponge?	

Figure 1. The three questions / photographs used to measure the proportion of spontaneous *Self* and *Other* responses for each group.

2.3 Design

The experiment had a 2 x 2 factorial design. Group (*TS*, *Control*) was the between-participants factor compared across two test questions (‘*what number is on the table?* & ‘*where on the table does she place her book?*’) and a baseline question (‘*where on the table is the sponge?*’). The within-participants factor was Perspective (*Self*, *Other*). The dependent variable was the proportion of *Self* (own perspective) and *Other* (actor’s perspective) responses for the two test questions and baseline question.

2.4 Procedure

All participants accessed the online study via an anonymized URL, which directed them to the participant information sheet (see **Appendix A)** that was read at their own pace. To increase the likelihood of spontaneous VPT, all participants were naïve to the purpose of the study. All participants provided consent by clicking a tick box presented on the screen, specifying that they understood the information about the study provided and could withdraw from the study without reason by exiting the web browser. After providing consent, participants were presented with task instructions for the spontaneous VPT task (see **Appendix B**).

For each of the eight questions, participants were shown the question with the photograph directly below it in the center of the screen. The question was presented in black ink, default font, size 18 pt and centralized at the top of the screen. Participants typed their response to the question in a text box located below the image, and then clicked an arrow to submit their response and progress to the next question. Each question was presented on a separate page and participants were not allowed to return to a previous question. Once they completed all questions, they were directed to a Pavlovia.org server hosting the second experiment.

2.5 Results

2.5.1 Coding

For the two test questions and baseline question, responses were coded as *Self* if the participant's answer referred to their own (egocentric) perspective and *Other* if their answer was from the actor's (allocentric) perspective. In cases where participants gave both perspectives in their response, the perspective that was mentioned first determined the coding category.

For the test question '*what number is on the table*?' responses that mentioned the word or number "six" were coded as *Self* and those that mentioned the word or number "nine" were coded as *Other*. For the second test question '*where on the table does she place her book*?', responses that were coded as *Self* were "right", "right side" etc. Responses that mentioned "on the left", "her left-hand side" etc were coded as *Other*. For the baseline question '*where on the table is the sponge*?', responses that were scored as *Self* were "on the left", "my left" etc and those scored as *Other* were "right side, "right" etc.

2.5.2 Data analysis

This experiment investigated whether there was a difference between the TS group and control group in the proportion of *Self* and *Other* responses across the three questions. The proportion of *Self* and *Other* responses are depicted in **Table 1**. We ran three separate analyses, one for each question related to spontaneous VPT.

For the baseline question, '*where on the table is the sponge?*' Fisher's exact test was used due to a small cell frequency (< 5, Kim, 2017). There was a significant difference in the proportion of *Self* and *Other* responses, $p = .043$ $\varphi = .255$, where the TS group gave fewer *Self* responses (66.66%) than the control group (92.68%).

For the first test question '*what number is on the table?*' a 2 x 2 Pearson chi-square test of independence demonstrated no significant difference in the proportion of *Self* and *Other* responses between both groups, $X^2(1) = .639$, $p = .424$, $\varphi = .099$.

For the second test question '*where on the table does she place her book?* there was a significant difference in the proportion of *Self* and *Other* responses between both groups, $X^2(1) = 7.74$, $p = .005$, $\varphi = .345$, with the TS group providing 12.5% *Self* responses compared to 46.34% from the control group. TS participants also gave more *Other* responses (87.5%) than controls (53.66%). Given that we found a significant difference between the *Self* and *Other*-perspective responses for this question we decided to investigate if this difference was due to left/right confusion, especially in the TS sample, who are known to have difficulty with spatial processing. Therefore, we excluded participants from both groups who gave an *Other*-perspective response to the baseline question and re-analysed the data with the remaining participants. The significant difference in the proportion of *Self* and *Other* responses between each group persisted, $X^2(1) = 5.26$, $p = .022$, $\varphi = -.318$.

Table 1. The proportion of *Self* and *Other* responses in the TS group ($N = 24$) and control group ($N = 41$) reported as a percentage for each of the three questions.

Column1	Column2	**What number is on the table?**	**Where on the table does she place her book?**	**Where on the table is the sponge?**
TS	Self	45.83% (11)	12.5% (3)	66.66% (16)
	Other	54.17% (13)	87.5% (21)	33.33% (8)
CON	Self	56.10% (23)	46.34% (19)	87.80% (36)
	Other	43.90% (18)	53.66% (22)	12.20% (5)

2.6 Discussion

Experiment 1 was designed to measure spontaneous level two VPT between those with TS and neurotypical controls. A paradigm similar to that designed by Tversky and Hard (2009) was used, where participants reported the presence of an object on the left and / or right-hand side of the visual field in relation to a human actor.

During this task, both groups were presented with eight photographs and each photograph was associated with a VPT question. Only three of these questions were used to measure to proportion of spontaneous *Self* and *Other* responses, whereas the remainder acted as fillers. For example, one image was associated with the test question '*what number is on the table?*' and showed a female actor looking at a digit '9' from her perspective but a digit '6' from the view of the participant. On the two remaining questions, participants had to verify the spatial location of a mundane object. One question was associated with an image showing the actor looking and reaching for an object ('*where on the table does she place her book*?'), whereas the other was a baseline question showing the visual scene and two objects on a desk but in the absence of the actor ('*where on the table is the sponge?*').

We found no significant difference in the proportion of *Self* and *Other* responses for the first test question '*what number is on the table?*' as both the TS group and Control group gave a similar proportion of *Self* (45.83% and 56.10% respectively) and *Other* responses (54.17% and 43.90% respectively). For the second test question '*where on the table does she place her book*?' there was a significant difference in the proportion of *Self* responses between both groups, with the TS group providing 12.5% *Self* responses compared to 46.34% from the Control group and TS participants providing 87.5% *Other* responses compared to 54.66% from the control group.

When one spontaneously adopts the perspective of another individual, it has been suggested that one typically performs a 'mental rotation' (MR) (Wang et al., 2015; Martin et al., 2019). This allows participants to imagine how a 3D object viewed from one perspective would look if it were rotated in space into a new orientation and viewed from a new perspective (Johnson and Moore, 2020). It is suggested that MR's are reflective of higher-order / executive processes, such as inhibitory control, cognitive flexibility (Nazareth et al., 2019) as well as visuospatial abilities (Podlogar and Podlesek, 2022). In the present study, if TS participants had a general inability to mentally rotate their own perspective to that of the actor's and correctly verify another individual's perspective, we would expect significantly more *Self* responses than *Other* responses for these two questions.

Only the second test question '*where on the table does she place her book*?' made explicit reference to the action of an actor and was unambiguous as to what perspective participants should adopt. One possibility is that the specific phrasing (i.e. the use of the word "she") in the question may have cued allocentric responding, resulting in the high percentage of *Other* responses in both groups, with TS participants reporting more *Other* responses than the control group. One possible explanation for the between group difference is that, because the question cued participants to adopt an allocentric perspective, the TS group, with their reduced social cognition skills, took this question literally and therefore adopted the agent's perspective. The control group, with greater social cognition skills, did not take the question quite so literally and hence showed a reduced effect induced by that leading question. However, given that we found a significant difference in the proportion of *Self*-perspective and *Other*-perspective responses between both groups for the baseline question ('*where on the table is the sponge*'), in which no actor was visible, and there was no leading question, this explanation seems unlikely.

How might we explain the group differences in the responses to the second test question? One possibility is that the participants experienced left-right confusion whilst giving a response. However, left-right confusion cannot explain the group differences in responses to the second test question (‘where on the table does she place her book?’), because this difference was still significant after we excluded *Other*-perspective responders from the baseline question and re-analysed the data.

As well as the two test questions, participants were required to answer a ‘baseline’ question: ‘*where on the table is the sponge?*’ This was the only question without the presence of an actor in the visual scene, so we did not expect participants to be responding from an *Other* perspective. Our results demonstrated that the proportion of *Self* responses was higher than *Other* responses for this question across both groups. This is consistent with the earlier findings reported by Tversky and Hard (2009). They found that when the actor was absent from the visual scene, participants generally defaulted to an egocentric perspective and gave significantly more *Self* responses. Yet when comparing the two groups, we found that TS participants gave a significantly greater proportion of *Other* responses (33.33%) compared to controls (12.20%). This was unexpected, as (1) with the actor being absent both groups should give significantly more *Self* responses than *Other* responses and (2) the proportion of *Self* responses should be similar across both groups. One explanation for this involves carry-over effects. The baseline question was always presented to participants last and TS participants generally gave a higher proportion of *Other* responses for the two questions that were presented prior to this one than controls. This may have resulted in more TS participants ‘primed’ to respond from the *Other* perspective by the time they were presented with this question, increasing the likelihood of reporting the *Other* perspective as a result.

3 Method for Experiment Two

3.1 Participants

The same participants that took part in Experiment 1 also completed Experiment 2, and no participants were excluded. Again, we did not test for handedness nor did we ask TS participants for proof of diagnosis. The financial/course credit compensation was only provided if participants finished both experiments to completion.

3.2 Stimuli

Stimuli for this experiment were identical to that used by Samson et al. (2010) and were accessed from https://doi.org/10.6084/m9.figshare.1455943.v1. The stimuli consisted of an image presented on the screen showing a lateral view into a three-dimensional (3D) room with the left, right and rear wall visible. Red coloured dots were displayed on one or two of the side walls. A 3D female human avatar was positioned in the center of the room and was always facing either the left or right wall (see **Figure 2**). As all participants in the present study were female, only the female avatar was used.

On half of the trials, the direction of gaze of the avatar meant that she could not see some of the coloured dots that were visible to the participants (*Inconsistent* perspective). For example, in half of the trials the avatar was facing towards the right wall with two dots presented on the left. In the remaining half of the trials, the avatar's position meant that she saw the same number of dots as the participant (*Consistent* perspective). The position of the avatar was kept constant across *Consistent* and *Inconsistent* trials, but the location of the coloured dots changed (See **Appendix G**).

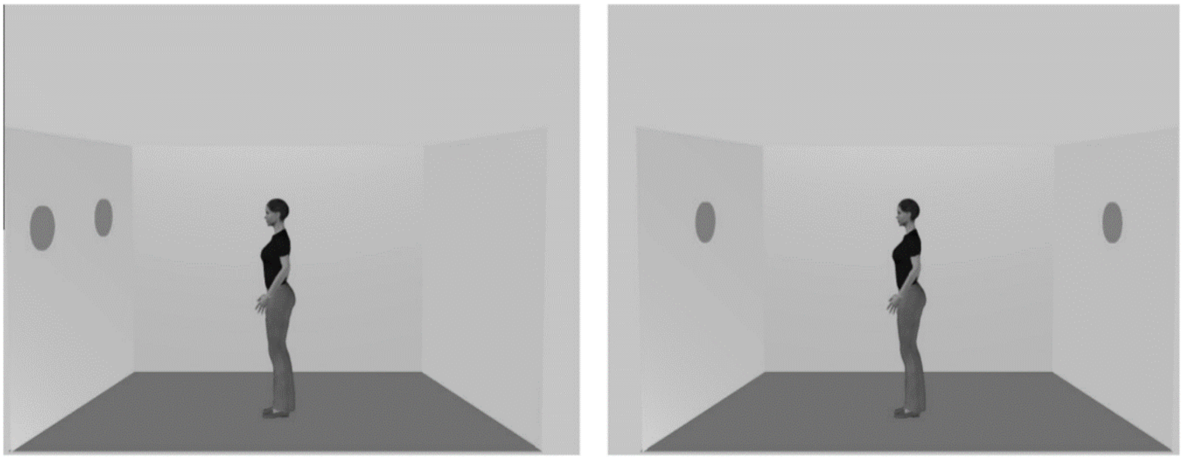


Figure 2. Example stimuli for the Dot Task, showing a *Consistent* trial and *Inconsistent* trial (image taken from Samson et al., 2010).

3.3 Design

The experiment had a 2 x 2 x 2 factorial design with Group (*TS* vs. *Control*) as the between-participants factor and Perspective (*Self* vs. *Other*) and Consistency (*Consistent* vs. *Inconsistent*) as within-participants factors. The dependent variables were reaction time (RT) in milliseconds, recorded for correct trials only, and error rate (ER). The ER represented the accuracy of participant's responses across all trials.

3.4 Procedure

After participants completed Experiment 1, they were automatically redirected from Qualtrics to the second online task hosted on a Pavlovia.org sever, coded using JavaScript. Participants were first presented with instructions with information regarding what they would see & how to respond (see **Appendix B**). They were also reminded to complete the entirety of the task in a quiet environment, without taking breaks. Each trial began with a fixation cross presented in the center of the screen for 750 ms. 500ms seconds later the word

'*YOU*" or "*SHE*" was presented in the center of the screen which indicated whether to take the perspective of the *Self* or that of the avatar (*Other*), respectively. 500 ms later, a single digit between 0 and 3 was presented at the center of the screen for 750 ms, this indicated the number of coloured dots the participant had to verify were there from the specified perspective.

Then, the image of the 3D room appeared on the screen until participants pressed one of two response keys, indicating whether the image matched or mismatched the word and number cue presented previously. The '*Y*' key was pressed if the number of red dots matched the information given previously and the '*N*' key was pressed if the number of dots did not match the perspective to be taken. If no response was provided after 2000 ms, the trial timed out and the next one started. The ratio of different to same trials was identical to that used by Samson et al. (2010). There were 96 matching trials, halved into 48 trials where participants had to take their own perspective and 48 where they had to take the perspective of the avatar. These were further subdivided into 24 *Consistent* trials and 24 *Inconsistent* trials. 16 filler trials were presented randomly with an equal number of *Self* and *Other*, *Consistent* and *Inconsistent*, matching and mismatching trials.

We did not change how the trials were presented by Samson et al., (2010). Therefore, we tested participants across four separate blocks each consisting of 52 trials in total, this included 48 test trials and 4 fillers. The order of the blocks was counterbalanced across participants and the order of the trials within each block was pseudo-randomised using the Microsoft Excel randomization tool. Care was taken so that there were no more than three consecutive trials of the same type. Furthermore, we ensured that there was an equal ratio of perspective shift to no-shift trials in each block, so that *Self* and *Other* trials were as often equally followed by the same perspective (no-shift) and by a different perspective (shift). To improve on the methodology used by Samson et al. (2010), we ensured that there was an approximately equal proportion of number cues (digit 0,1,2 or 3) in each block so that no number cue was more or less common in one block over another.

3.5 Results

We conducted a 2 x 2 x 2 mixed ANOVA with Perspective (*Self*, *Other*) and Consistency (*Consistent, Inconsistent*) as the within-group factors and Group (*TS*, *Control*) as the between-group factor. We ran two separate ANOVA's for the two dependent variables: RT (response-speed) and ER (response-accuracy).

3.5.1 Reaction time analysis

Mean RT's were calculated separately for each condition associated with Group, Perspective and Consistency. All trials that were either interrupted by timeout (5.3% of trials) or were not answered correctly (9.4% of trials) were removed from the data set prior to the analysis.

The ANOVA yielded a significant main effect of Perspective, $F(1, 63) = 4.29$, $p = .042$, $\eta_p^2 = .064$, where participants were faster verifying the perspective of the virtual avatar (M = 796ms, SD = 138ms) than their own (M = 805ms, SD = 161ms). There was also a significant Perspective × Group interaction, $F(1, 63) = 5.50$, $p = .022$, $\eta_p^2 = .080$. Paired t-tests revealed that only the TS group showed a significant Perspective effect, $t(47) = 2.53$, $p = .015$, with RT's being faster when they were asked to verify the perspective of the virtual avatar (M = 832ms, SD = 164ms) compared to their own (M = 860ms, SD = 194ms). Independent t-tests showed that the effect of Group was not significant, neither in the *Self* or *Other* condition.

We also found a significant main effect of Consistency, $F(1, 63) = 140.97$, $p < .001$,

η_p^2 = .691, where RT's were slower for *Inconsistent* trials (*M* = 858ms, *SD* = 160ms) than *Consistent* trials (*M* = 760ms, *SD* = 141ms) (see **Figure 3**). The ANOVA revealed a marginally significant effect of Group, *F*(1, 63) = 3.94, *p* = .051, η_p^2 = .059, but no significant interactions between Consistency and Group, *F*(1, 63) = 1.37, *p* = .246, η_p^2 = .021, Consistency and Perspective, *F*(1, 63) = 0.142, *p* = .707, η_p^2 = .002, or between Perspective, Consistency and Group, *F*(1, 63) = 1.04, *p* = .313, η_p^2 = .016.

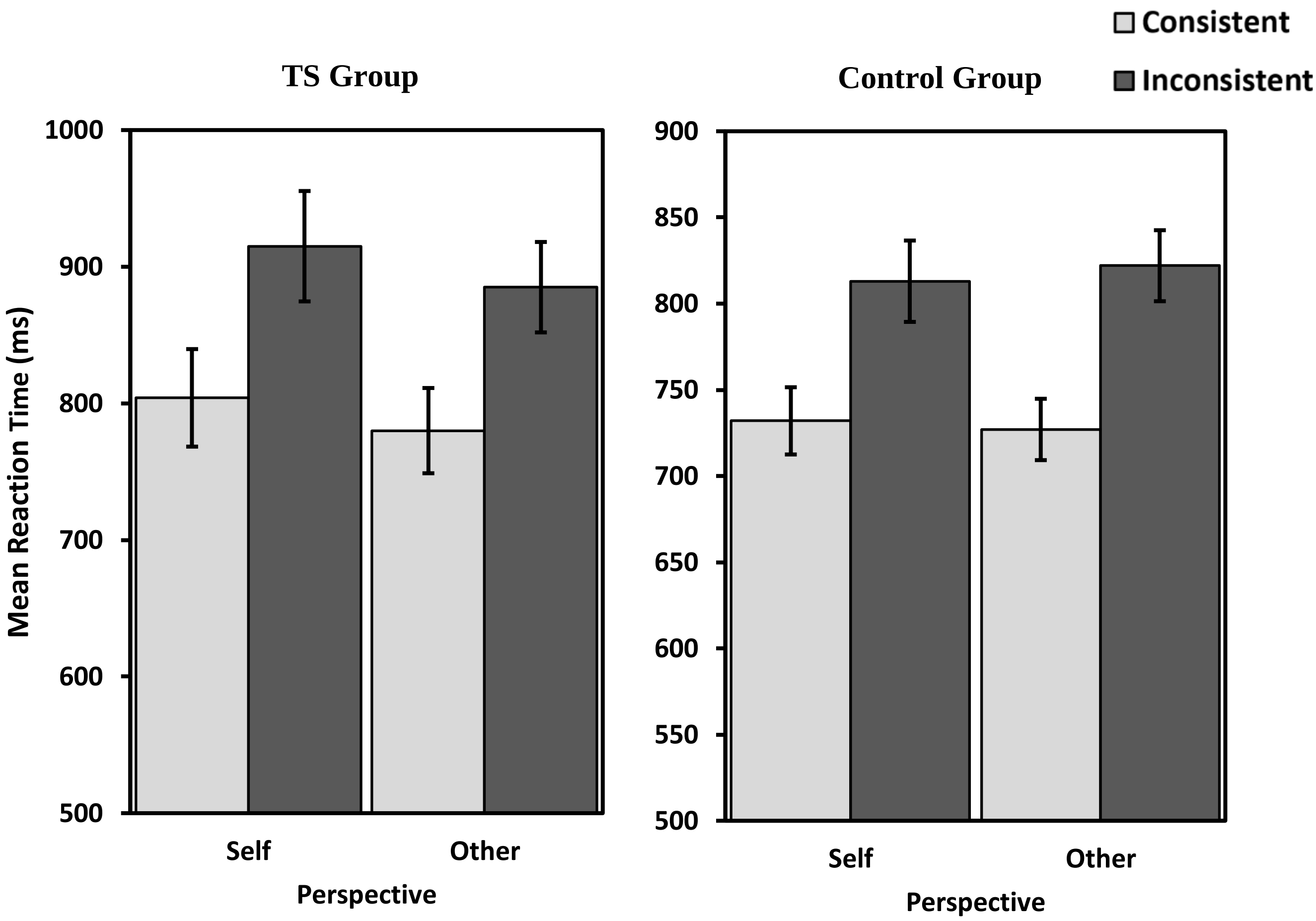


Figure 3. Mean reaction time (+/- SEM) as a function of Group (*TS*, *Controls*), Perspective (*Self*, *Other*) and Consistency (*Consistent*, *Inconsistent*).

3.5.2 Error rate analysis

The mean ER was calculated separately for each condition associated with Group, Perspective and Consistency. The mixed ANOVA yielded a significant main effect of Consistency, $F(1, 63) = 99.2$, $p < .001$, $\eta_p^2 = .612$, where participants made more errors on inconsistent ($M = 0.15$ errors, $SD = 0.14$) versus consistent trials ($M = 0.06$ errors, $SD = 0.10$) (see **Figure 4**).

There was no significant main effect of Group, $F(1, 63) = .041$, $p = .841$, $\eta_p^2 = .001$ or Perspective, $F(1, 63) = 1.71$, $p = .196$, $\eta_p^2 = .026$. Furthermore, there were no significant interactions: Perspective x Group, $F(1, 63) = .592$, $p = .445$, $\eta_p^2 = .009$, Consistency x Group

$F(1, 63) = .433$, $p = .513$, $\eta_p^2 = .007$; Consistency x Perspective, $F(1, 63) = 2.04$, $p = .158$, $\eta_p^2 = .03$; and Perspective x Consistency x Group, $F(1, 63) = .846$, $p = .361$, $\eta_p^2 = .013$.

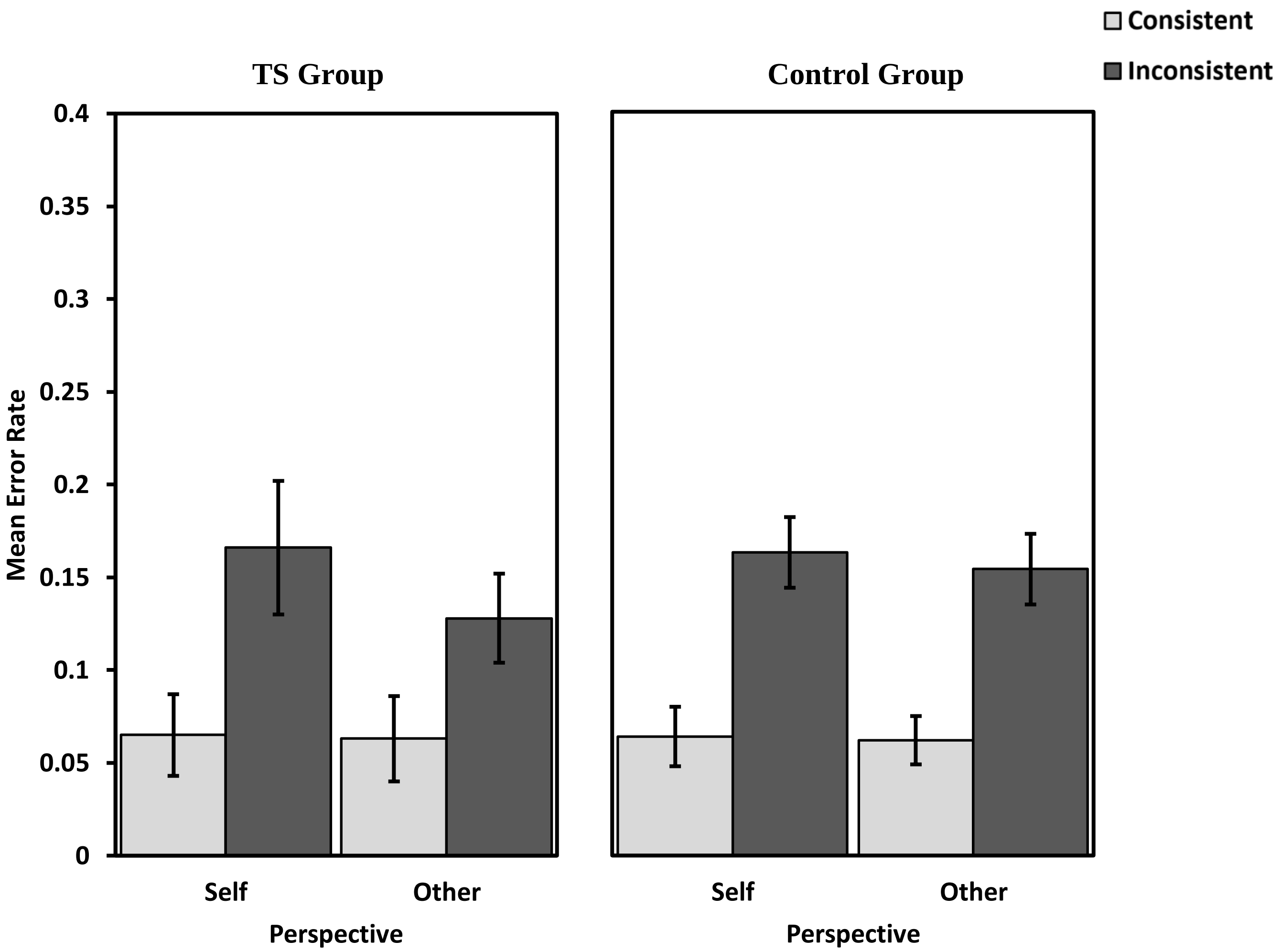


Figure 4. Mean error rate (+/- SEM) as a function of Group (*TS*, *Controls*), Perspective (*Self*, *Other*) and Consistency (*Consistent*, *Inconsistent*).

3.6 Discussion

Experiment 2 used the level one VPT paradigm designed by Samson et al. (2010) to measure implicit and explicit processing of perspectives between TS participants and controls. During this task, both groups were presented with the image of a 3D room and a female avatar stood at the center of the room gazing at one of two lateral walls. Participants were first provided with a cue informing them of which perspective to take (*Self*, *Other*) then a digit between 0 and 3 which indicated the number of dots on the wall they had to verify were visible. If the virtual avatar and participant saw the same number of dots, it was a *Consistent* trial but if they both saw a different number of dots, it was *Inconsistent*. The purpose of this task is to test whether someone's else's inconsistent perspective *interferes* with the processing of our down, which is evidenced by a longer response time and reduced accuracy when verifying the number of dots in the scene.

In our analysis of RT's, we found a significant effect of Perspective. However, given that we also found a significant Group x Perspective interaction, we followed up with pairwise t-tests which showed that only the TS group contributed to this effect with them being faster on *Other* compared to *Self* trials. The effect of Group was marginally significant but there was a significant effect of Consistency, where both groups were faster on *Consistent* trials than *Inconsistent* trials. We did not find a significant effect of Group. Regarding errors, we found a significant effect of Consistency, only there were significantly more errors on *Inconsistent* than *Consistent* trials. There was no significant effect of Perspective or Group, nor were there any significant three-way interactions between Group, Perspective and Consistency.

In this task, level one spontaneous VPT was measured by the extent to which the *Self* and *Other* perspectives interfered with each other. We found the same consistency effect as Samson et al. (2010), where the verification of a perspective is harder for participants if their own perspective differs to that of the avatar. In the present study, both groups were significantly slower and made more errors on *Inconsistent* trials than *Consistent* trials. This was due to the presence of both egocentric and allocentric intrusions: the participant's perspective interfered with the verification of the actor's and the verification of the participant's perspective was influenced by the avatar's respectively. The presence of intrusions in both groups was expected, given the robustness of the Consistency effect across a range of perspective-taking studies, including those exploring the phenomenon in neurotypical adults (Cole et al., 2016; Samson et al., 2010; Martin et al., 2019) as well as in disorders like autism (Schwarzkopf, 2014; Zwickel et al., 2011). Crucially, our results demonstrate that TS participants perform similarly to controls when two competing perspectives are incongruent.

In our analysis of RT's, both groups were slightly faster not in the verification of their own perspective but that of the avatar's. However, we also found a significant Perspective x Group interaction where only the TS group showed this effect. Perhaps the finding that they were faster in *Other* trials compared to *Self* trials could be explained by hormone replacement therapy. Between 11-13 years of age, HRT is given to TS patients typically in the form of exogeneous estrogen. The purpose of hormonal treatment is to induce puberty, maintain feminine sexual characteristics and prevent premature ovarian failure (Viuff et al., 2020; O' Donoghue et al., 2020). Estrogen may also play a role in neurotypical brain development, because of its neuroprotective properties for the frontal lobe and hippocampus (Maki, 2005; Ali, Begum & Reza, 2018). O' Donoghue et al. (2020) showed that specific brain regions of girls with TS may be more sensitive to estrogen than others, such as the basal ganglia and cerebellum. Most importantly, these areas may play an important role in perspective-taking (Healey and Grossman, 2018; Bukowski, 2018). In the present study, we did not control for previously administered HRT. As the mean age of our TS participants was 33 years old, it is plausible that most would have experienced at least one course of hormone therapy prior to the study. Therefore, past / present HRT may have acted as a potential confound in the present study.

In our analysis of accuracy, the only similarity to that for RT was a significant effect of Consistency, where both groups made significantly more errors on *Inconsistent* than *Consistent* trials but overall performance was comparable between them. This is consistent with findings reported by Samson et al. (2010) and further evidence for the idea that participants cannot easily ignore the irrelevant perspective (either their own or the avatar's), even when it goes against task demands (Schwarzkopf, 2014).

4 General Discussion

The present study explored spontaneous and non-spontaneous VPT in TS participants and controls across two online experiments. In Experiment 1, there was a significant difference between the TS and Control group for the test question '*where on the table does she place her book?*' where TS participants gave fewer *Self* responses than the control group. There was also a significant difference in answers to the baseline question '*where on the table is the sponge?*' where TS participants gave more *Other* responses than controls. The findings from both groups for the question '*where on the table does she place her book?*' are consistent with those obtained by Tverksy and Hard (2009), as they found that referring to an actor and / or action produced more spontaneous allocentric responses in neurotypical adults. The results from Experiment 1 suggest that TS participants can spontaneously adopt an allocentric perspective, when the question explicitly references the actions of another individual. Therefore, there is no evidence to suggest that those with TS have difficulties spontaneously taking an alternative perspective.

The findings from Experiment 1 are not consistent with other research exploring level two VPT in those with ASD. Some of the clinical features of TS are reminiscent of typical impairments in ASD (Wolstencroft & Skuse, 2019), such as social competence (Botha, Dibb & Frost, 2022), emotion recognition (Hong, Scaletta-Kent & Kesler, 2009), executive dysfunction (Le Page et al., 2011) and ToM (Hong, Dunkin & Reiss, 2011). One meta-analysis by Pearson, Ropar and Hamilton (2013) found that the performance of ASD participants was significantly worse than controls on a level two VPT task. They argued this might be due to difficulties in mentally rotating and transforming visuo-spatial information related to an allocentric perspective (Pearson, Ropar &

Hamilton, 2013). If TS shares features with the socio-cognitive profile of ASD, we might expect TS participants to perform in a similar way. However, compared to ASD, we obtained evidence that spontaneous level two VPT is spared.

In Experiment 2, participants were presented with the image of a 3D room and a female avatar in the center of the room. 0-3 red dots appeared on one of two lateral walls. Participants were told to report the number of dots from either their own perspective or that of the avatar's, as well as when the avatar's view was inconsistent with that of the participant. The main effect of *Consistency* was significant, as participants were slower and made more errors on *Inconsistent* than *Consistent* trials. The main effect of Perspective was also significant, and we also found a significant Perspective × Group interaction. Post-hoc tests revealed that only the TS group contributed to the Perspective effect. Overall our results suggest that TS participants have little to no impairment in either implicit or explicit VPT compared to neurotypical controls.

The findings from Experiment 2, measuring level one VPT, is further evidence for intact VPT in those with TS. We found that the RT and accuracy of TS participants was comparable to controls, irrespective of *Consistency*. Our study is the first to administer this paradigm to TS participants, but it has previously been given to those with HFA. For instance, Schwarzkopf et al. (2014) demonstrated that level one VPT was impaired in HFA participants when used explicitly (i.e. when asked to verify the avatar's perspective compared to their own) but not implicitly, evidenced by longer RT's and lower errors compared to controls. Although we did obtain a significant Group x Perspective interaction for RT, further analyses revealed that TS participants were in fact slightly faster verifying the avatar's perspective than their own. This is not consistent with Schwarzkopf et al's. (2014) research on HFA and leads us to conclude that like level two VPT, explicit level one VPT is generally unimpaired in TS.

We did obtain a significant effect of consistency for both analyses, where both groups were slower and made more errors on *Inconsistent* compared to *Consistent* trials. This is compatible with a great deal of research conducted previously using Samson et al's. (2019) paradigm (e.g. Schwarzkopf et al., 2014; Samson et al., 2010; Cole, Atkinson and Smith, 2016; Martin et al., 2018). These studies show that the *Consistency* effect is due to the presence of altercentric and egocentric interference. Our results only add to the robustness of the Consistency effect, indicating the reliability of the Samson et al. (2010) VPT paradigm.

As we were unable to demonstrate performance-related differences between TS participants and controls, whether those with TS have impaired mentalising abilities remains uncertain. In the second experiment, we observed altercentric interference in the TS group, although the extent of which was comparable to controls. In neurotypical controls, level one VPT requires less cognitive control and processing than level two, so such tasks may be computed by a faster, implicit mentalising system (Apperly & Butterfill, 2009; Santiesteban et al., 2014). If TS participants had a dysfunctional implicit system for mentalising, we would expect a significantly greater altercentric intrusion effect in the TS group compared to controls. Yet our results demonstrate that TS participants experience the same degree of interference as controls. As this implicit system of VPT matures early in the lifespan (~24 months) of neurotypical adults (Moll & Tomasello, 2006; Apperly & Butterfill, 2009), our results suggest this is also the case for those with TS. Other studies have found that mentalising is the result of sub-mentalising, rather than implicit processes (e.g. Santiesten et al., 2014; Heyes, 2014), whereby general memory and attentional processes give rise to altercentric interference. However, to date no studies have attempted to replicate these findings in TS. This provides an important avenue for future VPT and mentalising research in TS.

Research has demonstrated executive impairments in TS, which may be the result of functional deficits in the dorsolateral prefrontal cortex and frontoparietal regions (Hart et al., 2006). TS participants are known to have more pronounced difficulties with specific aspects of executive function, such as cognitive flexibility (Lepage et al., 2013; Mauger et al., 2018) and inhibitory control (Tamm et al., 2003). Many researchers agree these impairments may translate to deficits in perspective-taking (Hong et al., 2009). In the present study, participants were asked not only to shift flexibly between an egocentric and allocentric perspective, but also inhibit their own perspective when verifying the perspective of another. If TS participants do indeed have impaired executive functioning, we would expect significantly more errors than controls when they are asked to shift between perspectives, but this is not what we observed. It could be however, that impairments in these specific measures of executive function (cognitive flexibility and inhibitory control) do not necessarily translate to dysfunctional VPT. Therefore, we recommend that future work uses a wider array of cognitive tasks, to ascertain whether other aspects of executive dysfunction result in impaired VPT in TS.

The present study had a few notable limitations that should be addressed by future research. Firstly, the performance of both groups in Experiment 1 may have been influenced by carry-over effects, as they were shown a series of images. This contrasts with other studies, such as Tversky and Hard (2009), who presented participants with only one image and found that it elicited greater spontaneous perspective-taking. In the present study, participants might have been less naïve to the purpose of the study, despite being told to respond as quickly and accurately as possible. A future study may wish to replicate Tversky and Hard (2009) more closely by using only one photograph, to minimise non-spontaneous responding.

Furthermore, it could be argued that the phrasing of the second test question (‘*where on the table does she place her book?*’) provided participants with a social cue informing them of which perspective to adopt. As a result, after reading this question, they may have guessed that the ‘*Other*’ perspective was the correct and socially desirable viewpoint to report. This was unintentional and potentially could have reduced spontaneous responses. The consequences of phrasing a VPT question in this way was demonstrated by Tversky and Hard (2009), they found that ‘action questions’ elicited significantly more *Other* responses than ‘static questions’ that made no reference to an actor’s actions. Therefore, we advise that future researchers consider the wording of VPT questions carefully.

Another limitation is that the study was conducted online. Despite telling participants to complete the tasks in a private and quiet environment, the number of potential distractors could have been high. This is in comparison to more stringently controlled lab settings, used for the majority of VPT research (Samuel et al., 2021; Samuel, Eacott & Cole, 2022; Boffel & Musseler, 2019). Conducting the study online may have inflated the number of errors we obtained for experiment one. For example, previous research using the same paradigm has reported mean accuracy ratings of 2.5% (Samson et al., 2010), 6.7% and 6.2% (Schwarzkopf, 2014). Whereas in the present study, we obtained a mean accuracy rating of 10.5% for the TS group and 11.1% for the control group which are much higher than those announced previously. Another online-related limitation is that we did not ask TS participants for proof of diagnosis, so the TS group consisted of adults that self-reported their diagnosis. It is uncertain whether our sample of TS participants truly had a higher degree of TS-related features than controls. Therefore, future studies should consider obtaining proof of diagnosis from a certified medical professional, or at least consider screening TS participants with a standardised diagnostic questionnaire as evidence they have met the diagnostic criteria.

Additionally, we did not distinguish TS participants on the basis of karyotype or phenotype. This is important as there are many different TS karyotypes, the most common being 45,X (40-50% incidence) (Gravholt et al., 2022) followed by 46,XX (15-25%), isochromosome Eq (10%) and Y chromosomal material (10-12%) (Gravholt et al., 2022). However, only a few studies have found a robust correlation between TS karyotype and phenotypic features, and significant heterogeneity in the symptoms has been reported (Gravholt et al., 2002; Cameron-Pimblett et al., 2017). As different TS karyotypes influence the risk factor for thyroid disease (Cameron-Pimblett et al., 2017), celiac disease (Stoklasova et al., 2019) and diabetes (Elsheikh, 2002), it is possible that variations in Karyotype translate to variations in the cognitive profile of TS patients, including VPT. To date, no study has been conducted to explore this, which we believe provides an opportunity for future work to exploit. Until then, we can only advise that researchers control for the effect of karyotype and / or phenotype in future VPT research.

Overall, our results are the first to demonstrate that adults with TS do not show any significant differences in spontaneous perspective-taking (Experiment 1) or implicit / explicit perspective-taking (Experiment 2) compared to neurotypical adults. The present study adds to a growing body of knowledge exploring VPT across a range of clinical populations, including ADHD and autism. One major benefit of these results is that they may increase both the awareness and understanding of TS within the medical and research community.

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6 Appendices

Appendix A

Ethical Approval Letter

UNIVERSITY OF HULL

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PRIVATE AND CONFIDENTIAL
Thomas Thompson
Faculty of Health Sciences
University of Hull
Via email

24th January 2022

Dear Thomas

REF FHS401 - Visual Perspective-Taking in Turner Syndrome

Thank you for your responses to the points raised by the Faculty of Health Sciences Research Ethics Committee.

Given the information you have provided I confirm approval by Chair's action.

Please refer to the Research Ethics Committee web page for reporting requirements in the event of any amendments to your study.

Should an Adverse Event need to be reported, please complete the Adverse Event Form and send it to the Research Ethics Committee FHS-ethicssubmissions@hull.ac.uk within 15 days of the Chief Investigator becoming aware of the event.

I wish you every success with your study.

Yours sincerely

Professor Liz Walker
Chair, FHS Research Ethics Committee

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Appendix B

Experiment 1 Task Instructions

You will now complete the first task in the study.

In this task you will be presented with a series of 8 pictures and asked to answer a question about each picture.

Each picture and question will appear on the screen one at a time.

Please use the keyboard to type your response to each question in the text box below each picture.

Please respond to each question as quickly and accurately as possible.

You will not be allowed to return to a previous question.

Once you have typed your response, press the button on screen to progress to the next question.

When you are ready to begin the task, use the mouse to click the button below.

→

Appendix C

Experiment 2 Task Instructions

To respond when you see the picture, press the “Y” key if the number of dots matches the number you were given immediately beforehand, or the “N” key if the number of dots does not match the number.

Remember on some trials you need to respond based on what you can see (“YOU”), whereas on other trials you need to respond based on what the woman can see (“SHE”).

Press the Spacebar to move to the next screen.

To recap, for each picture you will see the following in this order:

(1) “YOU” or “SHE”, telling you whether to respond based on what you can see or what the woman can see
(2) A number
(3) The picture of the woman in the room

When the picture appears, press the “Y” or the “N” key, depending on whether the number of dots matches (“Y”), or does not match (“N”), the number you were just given.

Remember that the response you give will depend on whether you are responding according to what you can see (“YOU”) or what the woman can see (“SHE”).

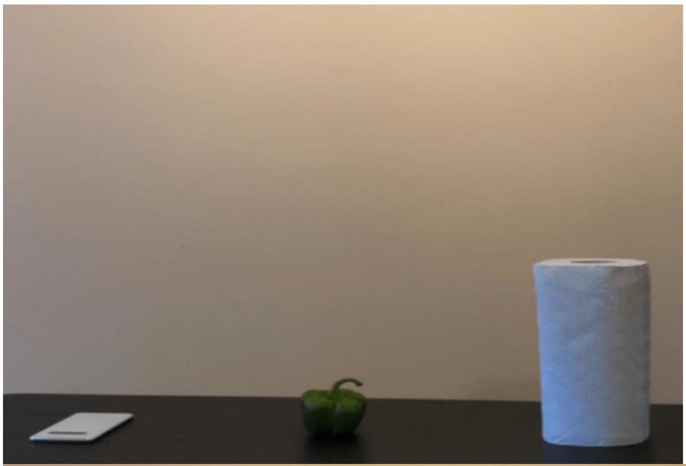
Please respond as quickly and as accurately as you can.

Press the Spacebar to move to the next screen.

Appendix D

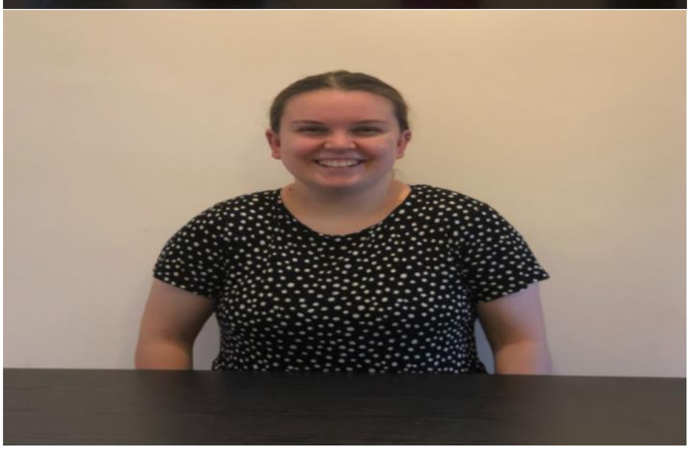
Experiment 1 Stimuli

What colour is the pepper?



How many objects are on the table?

Is she happy or sad?

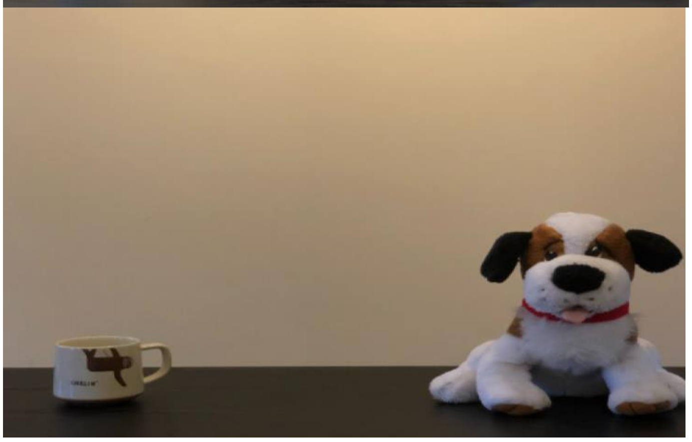


What colour is her vest/top?

What number is on the table?

Where on the table does she place her book?

Which object is bigger?



Where on the table is the sponge?

Appendix E

TS Group Digital Participant Information Sheet (PIS)

UNIVERSITY OF HULL | FACULTY OF HEALTH SCIENCES

Participant Information Sheet for Research Participants

Title of study: Visual Perspective-Taking Processes
Student researcher(s): Thomas Thompson (T.THOMPSON-2018@hull.ac.uk)
Supervising Academic Support Tutor(s): Igor Schindler (I.Schindler@hull.ac.uk), Kevin Riggs (K.Riggs@hull.ac.uk)

To participate in this study, you **must** have a working personal desktop computer / laptop with a stable internet connection. You are **not** allowed to use a mobile device / tablet to complete this study. You **must** also be female and at least 18 years old to participate in this study. Only females are eligible to take part as we are investigating perspective taking of those diagnosed with Turner Syndrome, which is a genetic disorder that only affects females.

What is the purpose of the study?
The purpose of the present research study is to explore visual perspective-taking processes. You will be asked to complete two online tasks in the same sitting and each task is designed to measure visual perspective-taking processes.

Why have I been invited to take part?
You are being invited to participate in this research study because you have a clinical diagnosis of Turner Syndrome.

What will happen if I take part?
If you agree to take part in this research study, you will be provided with a webpage link where you will complete both tasks, each task will be done in the same sitting and the entire study should take no longer than one hour. You will be asked to indicate the position of an object or symbol on the screen from either your own perspective or that of an actor's. You will use the keyboard to respond and both reaction time and accuracy of each response will be recorded. Task instructions will be presented on the computer screen before each task and will explain the procedure in more detail.

Do I have to take part?
Participation is completely voluntary. You should only take part if you want to. Choosing not to take part will not disadvantage you in any way. You do not need to provide a reason why you would prefer not to take part in this study. Once you have read the information sheet, please contact us by email if you have any questions that will help you make a decision about taking part. If you decide to take part, we will ask you to indicate that you give consent via an online consent form presented using the computer software.

What are the possible risks of taking part?
We do not foresee there being any significant risks in this research study.

What are the possible benefits of taking part?
You will receive a one-off payment in the form of an £8.00 Amazon voucher once you have fully completed the study. At the end of the study, you will be provided with a unique four-digit code and asked to email T.THOMPSON-2018@hull.ac.uk with your unique four-digit code to confirm you have fully completed the study in order to receive your voucher.

What will happen to my data? Data handling and confidentiality
Your data will be processed in accordance with the General Data Protection Regulation 2016 (GDPR).

- Your participation will remain confidential and your identity will at all times be anonymous and the final research paper will make no reference to you by name.
- Digital data will only be shared between the research team once it has been fully anonymised. Data will not be transferred to anyone else and will not be shared with any third parties.
- Digital data will be stored and accessed within Hull University-approved cloud computing services (e.g. box.hull.ac.uk) which will be passcode protected to ensure the data is fully secure, only the principal investigator will know the passcode.
- The principal researcher (Thomas Thompson) will have long-term custody of participant data for the 2021/2022 academic year. However, if the research is publishable, the supervising research team (Kevin Riggs, Igor Schindler) will be responsible for the custody of the data for a period of up to five years.

Data Protection Statement

The data controller for this project will be the University of Hull. The University will process your personal data for the purpose of the research outlined above. The legal basis for processing your personal data for research purposes under GDPR is a 'task in the public interest'. You can provide your consent for the use of your personal data in this study by completing the consent form that has been provided to you. Information about how the University of Hull processes your data can be found at [https://share.hull.ac.uk/Services/Governance/SitePages/Privacy%20notices.aspx].

You have the right to access information held about you. Your right of access can be exercised in accordance with the General Data Protection Regulation. You also have other rights including rights of correction, erasure, objection, and data portability. Questions, comments and requests about your personal data can also be sent to the University of Hull Information Compliance Manager Mr. Luke Thompson [dataprotection@hull.ac.uk]. If you wish to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk.

What if I change my mind about taking part?

You have the right to withdraw from the study without giving a reason at any time up until the point that the digital data is anonymised. Data will be anonymised automatically by the computer software once you have completed the two tasks & been presented with the debriefing information. Therefore, you have the right to withdraw at any point without reason before or during the study but you cannot withdraw your data afterwards.

What will happen to the results of the study?

The results of the study will be summarised in research report/thesis and may be published online to increase understanding of visual perspective taking in the scientific community.

Whom should I contact for further information?

If you have any questions or require more information about this study, please contact me using the following contact details: T.THOMPSON-2018@hull.ac.uk

What if I have further questions, or if something goes wrong?

If you wish to make a complaint about the conduct of the study, you can contact the University of Hull using the details below for further advice and information: FHS-ethicssubmissions@hull.ac.uk.

Appendix F

TS Group Digital Debriefing Sheet

UNIVERSITY OF HULL | FACULTY OF HEALTH SCIENCES

Version number v2.0 21/02/22

Research Participation Debriefing Information

Title of study: Visual Perspective-Taking Processes in a Turner Syndrome group and Non-Turner Syndrome Group
Student researcher(s): Thomas Thompson (T.THOMPSON-2018@hull.ac.uk)
Supervising Academic Support Tutor(s): Igor Schindler (I.Schindler@hull.ac.uk), Kevin Riggs (K.Riggs@hull.ac.uk)

Thank you for taking part in this research. Here is some additional information about the study.

Background and the research question:

The ability to inhibit one's own visual perspective and acknowledge someone else's is key to understanding the mental and emotional state of other people, which in turn allows for more successful social interaction and communication (Samson, Apperly, Braithwaite, Andrews & Bodley Scott, 2010). Research has shown that taking one's own visual perspective is effortless but taking a different perspective requires additional mental effort (Tversky & Hard, 2009). For example when asked to infer someone else's perspective, children typically respond with their own and even older adults still show a strong bias toward their own perspective, usually when trying to infer someone else's emotions or what they are thinking (Apperly, Samson, & Humphreys, 2000).

In the present study, we allocated participants to either a Turner Syndrome group or a non-Turner Syndrome (control) group and asked participants to complete two experimental tasks.

Turner Syndrome (TS) is a genetic condition which solely affects females and is medically characterised by the absence of a part or all of one of the sex chromosomes in the genome. According to the International Classification of Diseases (ICD), TS occurs in 1/2500 female births and involves deficits in visuospatial abilities and executive processes such as planning, theory of mind and inhibitory control. However, visual perspective-taking has not yet been explored in those with this condition. Therefore, the aim of the present study was to determine whether those diagnosed with Turner Syndrome (TS) have dysfunctional visual perspective-taking processes compared to a neurotypical control group.

The first task measured spontaneous perspective taking and compared the frequency of egocentric (own's own perspective) and allocentric (actor's perspective) responses between those with Turner Syndrome and those without. For example, a greater number of allocentric responses to the questions "what number is on the table?" or "where on the table does she place the book?" would suggest that participants spontaneously take the visual perspective of the female actor rather than their own.

The second task, the dot perspective task, measured automatic perspective taking. We presented both groups with the image of a 3D room with a female avatar in the centre gazing towards one of two lateral walls. You were asked to indicate how many dots you or the avatar could see. In consistent trials, the number of dots visible to you and the avatar were the same. In inconsistent trials, you could see some dots that the avatar could not. The purpose of this task was to ascertain whether those with Turner Syndrome found it harder to ignore what the avatar could see when asked to take their own self-perspective and if someone else's perspective interfered with reporting their own.

Anticipated findings:

In the spontaneous perspective-taking task, we hypothesise that those in the TS group will spontaneously take their own visual perspective more frequently than the perspective of the female actor, when compared to the non-TS control group. In the dot perspective task, we hypothesise that those in the TS group will make more errors and take longer to respond than the non-TS control group, when asked to inhibit their own perspective and take the female avatar's perspective.

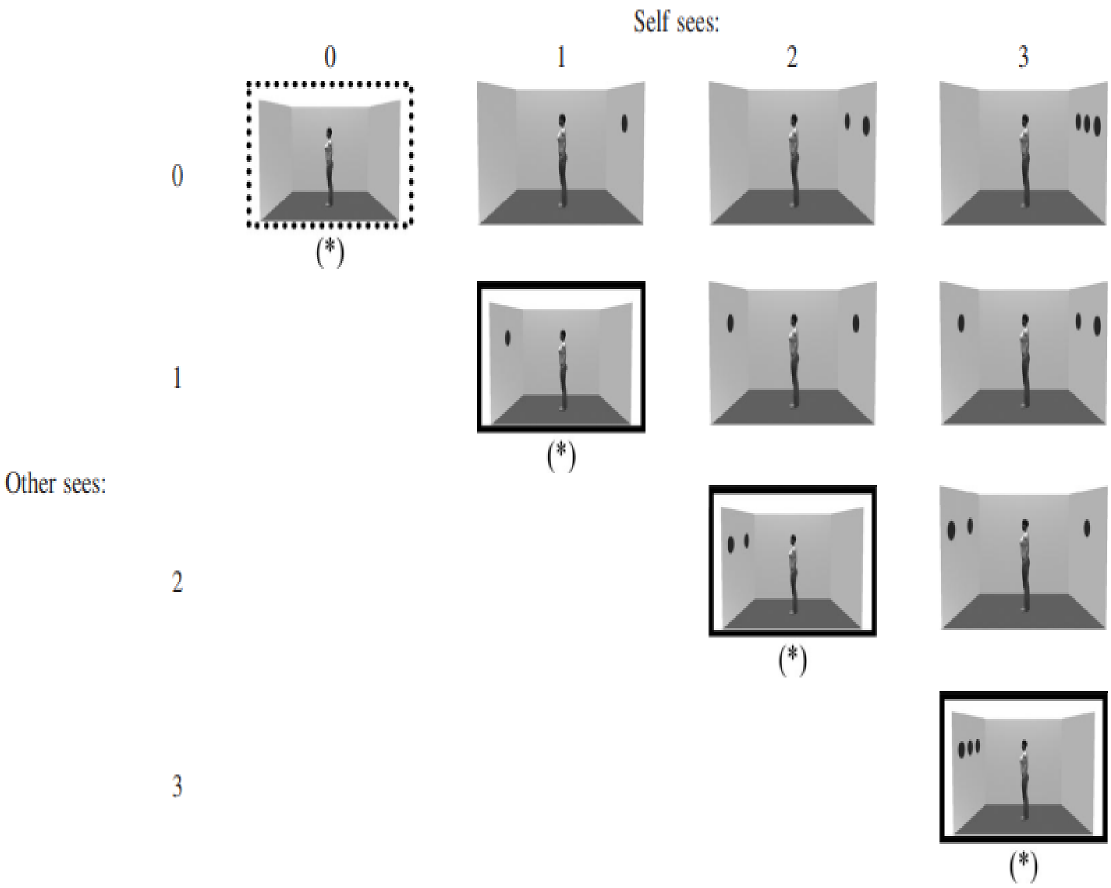
Further information:

We thank you again for your participation in this research study and we hope you found it both informative and enjoyable to complete. If you have any complaints, concerns or questions about this research study, please contact the principal investigator Thomas Thompson (T.THOMPSON-2018@hull.ac.uk), Igor Schindler (I.Schindler@hull.ac.uk) or Kevin Riggs (K.Riggs@hull.ac.uk).

Appendix G

Experiment 2 Stimuli (taken from Samson et al., 2010)

Pictures bordered with a full line show the consistent stimuli; the picture bordered with a dashed line shows the consistent stimulus presented as filler trials, and the non-bordered pictures show the inconsistent stimuli. The mirror image of each of these stimuli was also presented in the experiment.



* These stimuli were repeated twice as often as the other stimuli in order to balance the overall number of consistent and inconsistent trials.