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TITLE

The way others move can influence what we choose

AUTHORS

Paul A. G. Forbes[1]*, Steph F. Suddell[2], Harry Farmer[3],

Yanakan Logeswaran[1], and Antonia F. de C. Hamilton[1]

*Corresponding author: paul.forbes.13@ucl.ac.uk

[1]Institute of Cognitive Neuroscience, University College London, United Kingdom

[2]School of Experimental Psychology, University of Bristol, United Kingdom

[3]Department of Psychology, University of Bath, United Kingdom

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ABSTRACT

Whether pointing at a menu item or rifling through a clothes rack, when we choose we often move. We investigated whether people's tendency to copy the movements of others could influence their choices. Participants saw pairs of pictures in private and indicated which one they preferred. They then entered a virtual art gallery and saw the same pictures pairs in the presence of a virtual character. Having observed the virtual character point to indicate her preference with either a high or low movement trajectory, participants indicated their preference. There was either an anatomical (same movement, same choice) or spatial correspondence (same movement, different choice) between the participant's pictures and those of the virtual character. We found that participants copied the movement made by the virtual character rather than her action goal (i.e. her choice of picture). This resulted in a shift towards the virtual character's preferences in the anatomical condition but away from her preferences in the spatial condition. This effect was driven by the observation of the virtual character's high pointing movements. In a further experiment, we did not find any significant differences in imitation behaviour in autism, although autistic participants were less consistent in their choices. Our findings demonstrate that we are not only influenced by other's choices but also the types of movements others make to indicate those choices.

INTRODUCTION

Imagine you are at a restaurant with a friend and the waiter is taking your order. Your friend points emphatically at the menu indicating the particular meal she wants. When the waiter asks you what you want you point at the same item on the menu. Why did you make the same choice as your friend?

Typical explanations offered by theories of social influence (e.g. Cialdini & Goldstein, 2004) stress your desire to affiliate with your friend and/or your belief that she has superior knowledge to you (perhaps she has been to the restaurant before). In support of this explanation a range of studies have demonstrated that our choices are influenced by our affiliative motives (Izuma & Adolphs, 2013; Midgley, Dowling, & Morrison, 1989) and by others' perceived expertise (Lauring et al., 2016; Plassmann, O'Doherty, Shiv, & Rangel, 2008). Yet, a limitation of these studies is that the social context is only implied (Berns, Capra, Moore, & Noussair, 2010; Campbell-Meiklejohn, Bach, Roepstorff, Dolan, & Frith, 2010; Plassmann et al., 2008). That is, although participants are informed of the choices of a particular person or group, they do not witness others indicating those preferences. However, as with you and your friend at the restaurant, people often move to indicate their preferences to others, or, as Schall (2001) highlighted "Often one does one thing (order a meal) by doing something else (point at the menu)" (Schall, 2001).

Thus, it could be that when we observe others making choices, we are not only influenced by their choices (i.e. their action goal) but also the types of movements they make to indicate their choices. This is what we explored in the current study – when we make choices in the presence of others, are our choices influenced by the types of movements others make to indicate those choices? This distinction between copying the choice (or goal) of an action compared to a particular movement maps onto an influential theory of imitation (Bekkering, Wohlschläger, & Gattis, 2000; Wohlschläger, Gattis, & Bekkering, 2003). Thus, we place our study of social influence in the context of motor studies of imitation, and consider what these might predict about people's imitative tendencies. In the literature review below, we consider how people's choices might be influenced by the goal of another's action, by the topographical matching between the model and imitator's action, and by social cues conveyed in the kinematics of the action. In Experiment 1, we draw on these theories to build our hypothesis of how neurotypical people's choices will be influenced by seeing another's actions. In Experiment 2, we compared the imitation behaviour of autistic participants and a matched neurotypical group - autistic individuals have been shown to focus on goals during imitation (Hobson & Lee, 1999) and may show differences in their responses to social cues when modulating their imitation behaviour (Wang & Hamilton, 2012).

Copying goals vs. copying kinematics

The theory of goal-directed imitation (GOADI; Wohlschläger et al., 2003) states that during imitation people decompose an action into a hierarchy of goals in which the ends of an action (e.g. the particular item your friend pointed to on the menu) are further up the hierarchy than the means (e.g. the particular movement your friend made to indicate her choice). Actions at the top of the hierarchy are more readily imitated and, according to the ideomotor principle, the selected goal activates the motor programme most readily associated with it (Prinz, 1990). GOADI is largely supported by studies which have characterised people's errors and movements during imitation tasks. These show both that children are primarily concerned with copying the goal of an observed action (e.g. touch ear) and that they are less concerned about the kinematics of the action (e.g. touch ear with a crosslateral movement) (Bekkering et al., 2000). Similarly, studies which have recorded participants' kinematics during imitation tasks show that when goals are present participants do not copy the speed of the model's action, but are more likely to do so when the goals are absent (Wild, Poliakoff, Jerrison, & Gowen, 2010, 2012).

In line with this, studies of mimetic desire show that people tend to choose the same item as others (Lebreton, Kawa, Forgeot d’Arc, Daunizeau, & Pessiglione, 2012), and tend to like things that others like (Campbell-Meiklejohn et al., 2010). Together these findings suggest that imitation behaviour is driven by the goal of an action, and that kinematic information is often ignored. One goal of the present study was to test if this is true in a rich virtual reality context.

This focus on goals during imitation is particularly the case for autistic individuals who tend to copy the goal of an action but not the style with which the goal was achieved (Forbes, Pan, & Hamilton, 2016; Hobson & Lee, 1999), and, show increased goal-directed eye movements during imitation tasks (Wild et al., 2012). This inclination towards goal-directed imitation in autism is explored further in Experiment 2.

Imitating anatomically vs. imitating spatially

When imitating other people we can copy the topography of their action (match their movement anatomically), or, we can match their movement spatially (make a movement to the same spatial location). When there is a topographical matching between the movement of a model and that of an imitator, imitation is enhanced. For example, Brass et al. (Brass, Bekkering, & Prinz, 2001) showed that participants are faster at imitating finger movements when the observed hand is presented in the same configuration as their own. Similarly, Ramenzoni, Sebanz and Knoblich (Ramenzoni, Sebanz, & Knoblich, 2015) found that the ability to tap synchronously with a model was modulated by the topographical congruency between the model and participants’ hands. Automatic imitation effects are also strongest when they are effector-specific; for example, participants are faster to make hand opening movements having observed hand opening compared to mouth opening (Leighton & Heyes, 2010). Pan and Hamilton (2015) found that participants showed a greater tendency to copy another agent when they could map the actions of another agent onto their own body. They asked participants to perform simple tapping sequences with three drums which were either the same (congruent) or different (incongruent) from the sequences performed by a virtual character or a bouncing ball. There was either a spatial or anatomical matching between the drums of the virtual character (or ball) and those of the participant. In the spatial condition, the participants displayed no imitative advantage for the virtual character compared to the ball. It was only in the anatomical condition - when there was a topographical match between participants and virtual character - that participants showed an imitative advantage for the virtual character. These studies demonstrate that imitative tendencies are enhanced when there is a topographical matching between the movements of the model and that of the imitator. The current study investigated whether people's tendency to match the movements of another agent topographically could influence their choices.

Communicative kinematics

The fact that we change our movements according to the social context was noticed by Darwin who highlighted how we often "wish to make certain gestures conspicuous or demonstrative" (Darwin, 1872). The advent of motion tracking technologies has provided us with a detailed understanding of these differences (Krishnan-Barman, Forbes, & Hamilton, 2017). Peeters et al. (2013) showed that, when participants had a communicative intent, the duration of their pointing movement was longer as was the time they spent at the apex of the point (Peeters, Chu, Holler, Özyürek, & Hagoort, 2013). Similarly, Cleret de Langavant et al. (2011b) showed that the trajectory and endpoint variability of pointing movements changed depending on whether social context was communicative or not. These findings are consistent with a range of studies which have demonstrated that the kinematic features of other people's movements can reveal a wealth of information about their psychological states (Becchio, Koul, Ansuini, Bertone, & Cavallo, 2017; Krishnan-Barman et al., 2017). For example, actors who intend to cooperate will move with a slower and exaggerated trajectory (Quesque, Delevoye-Turrell, & Coello, 2015; Vesper, Schmitz, Safra, Sebanz, & Knoblich, 2016) and when participants observe another agent make a movement more quickly, they rate their decision as more confident (Patel, Fleming, & Kilner, 2012). In sum, when we are in the presence of people we often change the kinematics of our movements in order to communicative with them. For example, to return to our restaurant example, your friend may want to draw the waiter's attention to her choice so points at the menu with a slow and exaggerated movement trajectory. What remains unknown however is the extent to which these differences in kinematics influence people's tendency to copy other's movements (Experiment 1), and, whether there are any differences in this behaviour in autistic individuals (Experiment 2) who may show differences in their sensitivity to social cues and the subsequent modulation of their imitative responses (Wang & Hamilton, 2012)

The current study: Experiment 1

Knowledge of other people's choices (without any observation of their action) can influence our own choices (Campbell-Meiklejohn et al., 2010; Izuma & Adolphs, 2013). The aim of Experiment 1 was to test if this effect varies when more detailed information is available about the kinematics of the other person's action. A review of previous studies of imitation behaviour highlights three key findings which can lead to predictions for our task:

(1) when instructed to copy a model's action participants tend to copy the goal ahead of the kinematics (Wohlschläger et al., 2003). This aligns with social influence models which suggest that people tend to like things that others like (Campbell-Meiklejohn et al., 2010; Izuma & Adolphs, 2013).

(2) during imitation if there is a topographical (i.e. anatomical) match between the observed and executed movement, imitation is enhanced (Pan & Hamilton, 2015).

(3) when we aim to communicate with others we modulate the kinematic features of our actions (Peeters et al., 2013).

Experiment 1 aimed to explore imitation and social influence in an ecologically valid, virtual reality setting. Many previous studies of imitation have usually involved just one goal (e.g. touch ear; Bekkering et al., 2000) or no goal at all (Wild et al., 2010). These studies have found that when a goal is present we prioritise copying the goal of the action rather than the type of movement made to achieve the goal (Bekkering et al., 2000; Wohlschläger et al., 2003). If no goal is present in the observed action, we pay more attention to the type of movement made and imitate this more reliably. But what happens when we have a choice of goals as is common in many everyday situations, such as in a restaurant (Gattis, 2002)? Do we still copy the observed goal at the expense of the movement, or, does the type of movement influence our movements and our choices?

To test this, participants were shown pairs of art pictures and indicated which one they preferred. They then entered a virtual art gallery and saw the same pictures pairs in the presence of a virtual character who sat opposite them. In the art gallery, the virtual character pointed to the picture she preferred before the participant indicated their preference. In the art gallery there were two conditions (Figure 2). In the spatial condition, there was a spatial correspondence between the picture pairs of the virtual character and those of the participant so choosing the same picture as the virtual character meant making a different movement to her. In the anatomical condition, there was an anatomical correspondence between the picture pairs of the participants and those of the virtual character so choosing the same picture meant making the same movement.

The primary aim of Experiment 1 was to test whether seeing the choices of the virtual character could change the choices participants had made in private. We can contrast two main hypotheses:

Goal hypothesis – if participants copy the virtual character's goal (i.e. her choice of picture), then in both the anatomical and spatial conditions participants should shift their choices to match those of the virtual character (Campbell-Meiklejohn et al., 2010; Wohlschläger et al., 2003).

Movement hypothesis – if participants copy the virtual character's movements, then in the anatomical condition participants should shift their preferences towards those of the virtual character as making the same movement as the virtual character involved making the same choice as her. Whereas, in the spatial condition, participants should shift their preferences away from those of the virtual character as making the same movement as the virtual character involved making a different choice to her (Figure 2).

The second aim of Experiment 1 was to test whether the kinematic properties of the virtual character's pointing movements, specifically the height of her point trajectory, could also influence people's movements and choices. If the virtual character pointed with an exaggeratedly high trajectory, which has been shown to be communicative (Peeters et al., 2013), would participants be more likely to copy the goal of the observed action (i.e. the picture choice) or the type of movement made?

EXPERIMENT 1

METHOD

Design and participants

The study followed a 2 x 2 design with configuration (anatomical vs. spatial) and height (high vs. low) as within-subject factors. The dependent variable was shift – how much participants shifted their preference either towards or away from those of the virtual character from the private to the social setting.

39 participants (25 female) with a mean age of 29 years (SD = 10 years; range 18-59) were recruited from the UCL Institute of Cognitive Neuroscience participant database. We aimed for a sample of 40 participants to be at the upper end of previous imitation studies which typically used 30-40 participants (e.g. Pan & Hamilton, 2015). One participant failed to turn up on the last testing day resulting in the final sample size. All participants were right-handed, had normal or corrected-to-normal vision and reported no history of neurological disorder. All were financially reimbursed for their time and gave written informed consent before participating. All procedures were approved by the UCL Research Ethics Committee.

Materials

80 picture pairs in total were selected from a sample of 240 images (120 landscape and 120 abstract) which were rated by an independent group of 20 participants on their complexity, concreteness, attractiveness, valence, affectivity and interest using a 7-point scale. The luminance and contrast were also calculated for each image using MATLAB (MathsWorks, Natick, USA). The best matched 40 landscape pictures and the best matched 40 abstract pictures were then selected for the current study. A landscape picture always appeared with another landscape picture and an abstract picture always appeared with another

abstract picture. All 80 picture pairs (40 landscape pairs, 40 abstract pairs) were presented in the private setting. In the social setting 40 of these were presented in the anatomical condition and 40 in the spatial condition. The same pictures always appeared in the anatomical and spatial conditions for all participants. In both the spatial and anatomical condition, the virtual character pointed with a high trajectory to indicate her preference on 20 trials and with a low trajectory on the other 20 trials. The landscape and abstract pictures pairs were distributed evenly across all the conditions.

The virtual character's movements were animated using pre-recorded motion capture data from a female actor using three magnetic markers (Polhemus LIBERTY system, Colchester, USA) attached to the head, the top of spine, and right index finger. When recording the movements, the actor was instructed to look from side-to-side before pointing with either a high or low movement trajectory (peak height of approximately 16 cm or 2 cm, respectively). The motion capture data was mapped on to the virtual character using MotionBuilder (http://www.autodesk.com/motionbuilder) and Vizard (WorldViz Inc, Santa Barbara, USA).

Procedure

Private setting.

In the private setting participants sat in front of a 61 cm monitor and saw each picture pair for 5 seconds before the picture pairs disappeared. A question then appeared which said "Which picture do you prefer?" and participants had 2 seconds to indicate their preference by pressing the 'a' key on a keyboard if they preferred the picture on the left of the screen or the 'l' key for the picture on the right of the screen. A fixation cross appeared for 500 ms before the next picture pair appeared (see Figure 1). Responses were recorded in MATLAB and picture presentation was controlled using the Cogent toolbox (http://www.vislab.ucl.ac.uk/cogent.php). Each picture was presented on an 11.5 cm x 11.5 cm area with any excess spaced filled black (see Figure 1).

[insert Figure 1 about here]

Social setting.

After making their choices in the private setting participants made the same choices in the social setting - the virtual art gallery. Participants sat at a table on a stool and had a magnetic marker (Polhemus LIBERTY system, Colchester, USA) attached to their right index finger to record their movements. The virtual environment was presented on a 160 cm x 90 cm projector screen approximately 70 cm away from the participant using Vizard (WorldViz Inc, Santa Barbara, USA). The virtual environment depicted a female virtual character in the middle of the screen facing the participants. The virtual character's pictures were on the table in front of her and appeared on 25 cm x 25 cm placeholders. There were labels below the placeholders on the table with an 'A' or 'B' on a white tile below them. The participants' pictures were suspended to the left and right of the virtual character in 33 cm x 33 cm placeholders (see Figure 2).

[insert Figure 2 about here]

The table which the participants sat at had three white markers: a resting pad labelled 'X' in immediately in front of the participant, 20 cm in front of the participants and 40 cm to the left and right were white markers labelled 'A' and 'B.' If participants moved the magnetic marker on their right index finger onto either label on the table then the corresponding label under their pictures on the projector screen were highlighted with a yellow border (see Supplementary Video).

The start of each trial was signalled by a beep with the virtual character's and participant's right index finger in their respective resting positions. The virtual character's pictures pairs appeared on the table in front of the virtual character and the participant’s pictures in the place holders either side of her. The pictures stayed on the screen for 6500 ms during which the participants were instructed to decide which picture they preferred but not to move their finger from the resting position. The virtual character also looked at the pictures as if she were deciding which picture she preferred. After 6500 ms all the pictures disappeared and a “ding” sound occurred which acted as the virtual character’s cue to move. The virtual character then pointed to either the ‘A’ or ‘B’ label on the table to indicate her preference. The label the virtual character pointed to was highlighted with a yellow border and she returned her finger to the resting position. 1500 ms after the “ding” sound, a “dong” sound occurred which acted as the participant’s cue to indicate their preference by using their right index finger to point to either the ‘A’ or ‘B’ on the table in front of them. Once they had pointed, their A or B label on the screen was also highlighted with a yellow border to indicate their preference. The participant then returned their right index finger to the resting position. After the “dong” sound, participants had 3000 ms to respond before the beep signalled the start of the next trial and the next picture pair appeared (see the Supplementary Video for examples of the trial structure).

The participants completed two blocks in the social setting - one anatomical block and one spatial. The order of these was counterbalanced across participants. Participant were given 8 practice trials at the start of the experiment. This was always in the condition they encountered in the first block. At the start of the second block, the participants completed two or three practice trials in the new condition so that they were made aware of the difference in layout of the virtual character’s pictures. However, their task remained the same in both the anatomical and spatial condition - if they preferred picture A they pointed to ‘A’ to their left on the table in front of them whereas if they preferred picture B they pointed to the B on their right on the table in front of them (See Figure 2).

At the end of the experiment participants were asked to indicate how interested they were in art on a 7-point Likert scale and to indicate the number of times they had attended an art gallery or exhibition in the past 12 months.

RESULTS

Excluded data

Failure to choose in the private task.

In the private setting, participants had 2 seconds to indicate which picture they preferred after having viewed the pictures for 5 seconds. However, on 5.0% (SD: 5.5%) of trials participants did not respond quickly enough so their preference could not be recorded (note we addressed this issue in Experiment 2). These trials were excluded from the analysis as it was not possible to establish whether participants later shifted their responses on these trials in the social setting. There were no significant differences in the number of these ‘timed out’ trials in the picture pairs which later appeared in the anatomical, 4.7% (4.9%), and spatial, 5.4% (6.8%), conditions.

Failure to choose in the social task.

On 2.5% (3.3%) of trials participants failed to indicate their choice in the social task. These trials were excluded from the analysis. These ‘no choice’ trials were identified by plotting the kinematic data for each participant for each trial and identifying trials in which no clear pointing movement was made during the 3000 ms response period. There were no significant differences in the number of trials excluded for the anatomical, 2.9% (5.5%), and the spatial, 2.0% (2.9%), condition.

By combining both these exclusion criteria a total of 7.3% (6.8%) of trials were excluded. There were no significant differences in the total number of trials excluded for the anatomical, 7.5% (8.1%), and the spatial, 7.1% (7.3%), conditions.

Preference analysis

Agreement with the virtual character's pre-specified choices: potential to shift.

The virtual character's choices were pre-specified. She made the same choice and movement for every participant for every picture pair. This is the advantage of using virtual characters as they behave consistently across participants (Pan & Hamilton, 2018). However, it was possible that in the private setting participants' choices may have coincidently matched a large percentage of the virtual character's pre-specified choices. For example, if participants matched the pre-specified choices of the virtual character on 100% of trials in the private setting, then it would not have been possible for them to shift their preferences towards those of the virtual character in the social setting (as they already agreed with all of her choices). Similarly, if participants did not match any of the virtual character's pre-specified choices in the private setting, this would have given the participants more potential to shift their preferences towards those of the virtual character in the social setting.

However, this was not the case - participants matched the pre-specified choices of the virtual character between (min) 39.9% and (max) 61.1% in the private setting (M = 49.3%, SD = 5.38%) and this did not differ between the picture pairs which would later appear in the anatomical (M = 49.5%, SD = 7.22%) and spatial (M = 49.2%, SD = 7.17%) conditions. Thus, participants had the potential to shift their preferences on approximately 40-60% of trials in the social setting. In the social setting participants matched the pre-specified choices of the virtual character between (min) 39.4% and (max) 66.4% (M = 49.3%, SD = 6.09%) ($t_{38} = -0.087$, $p = 0.931$, $d = -0.013$). Therefore, the overall extent to which participants matched the choices of the virtual character in the social setting did not change from the private setting (although differences were found between the different conditions, see below).

Shift in choice

Consistency.

The consistency of participants' choices for each picture pair were compared between the private and social setting. On average in the social setting participants stuck with their choice from the private setting on 78.1% (*SD* = 11.2%) of trials. Greater consistency in participants' choices was significantly correlated with the number of times they reported visiting an art gallery in the past 12 months $r(37) = 0.400$, $p = 0.012$, but was not significantly correlated with self-reported interest in art, $r(37) = 0.285$, $p = 0.079$. Mean (SD) number of gallery visits in the last 12 months was 5.46 (3.54) and participants' mean (SD) self-reported interest in art (on a 1-7 point Likert scale) was 5.23 (1.35).

Preference shift.

On 21.9% of trials participants changed their picture choice from the private to the social setting. Next we investigated whether this preference shifting varied across conditions and if participants shifted their preferences towards or away from the preferences of the virtual character. If participants made the same choice in the private setting compared to the social setting, then this trial was assigned a 0. If participants changed their preference in the social setting so that they chose the same picture as the virtual character, the trial was assigned a +1. Finally, if participants changed their choice in the social setting so that they chose the different picture to the virtual character, the trial was assigned a -1.

The scores in each condition (anatomical-high, anatomical-low, spatial-high, and spatial-low) were then summed, divided by the number of valid trials in that condition and then multiplied by 100 to give a shift score as a percentage for each participant. Each shift score could therefore range from -100% to 100% with negative scores indicating a shift away from the choices of the virtual character and a positive score indicating a shift towards the choices of the virtual character.

A 2 (configuration: anatomical vs. spatial) x 2 (height: high vs. low) within-subjects ANOVA was conducted on the shift scores. This revealed a main effect of configuration ($F_{1,38} = 4.27$, $p = 0.046$, $\eta_p^2 = 0.101$) with participants shifting towards the virtual character's preferences in the anatomical condition ($M = 1.79\%$, $SD = 8.27\%$) and away from the virtual character's preferences in the spatial condition ($M = -1.74\%$, $SD = 6.69\%$). The main effect of height was not significant ($F_{1,38} = 1.51$, $p = 0.226$, $\eta_p^2 = 0.038$). However, the interaction between configuration and height was significant ($F_{1,38} = 4.84$, $p = 0.034$, $\eta_p^2 = 0.113$).

[insert Figure 3 about here]

Post-hoc paired samples t-test revealed that in the high condition shift scores in the anatomical ($M = 2.70\%$, $SD = 11.7\%$) configuration were significantly greater than the shift scores in the spatial ($M = -4.79\%$, $SD = 8.26\%$) configuration ($t_{38} = 3.20$, $p = 0.003$, $d = 0.512$). However, there was no significant difference between shift scores in the anatomical ($M = 0.886\%$, $SD = 11.8\%$) and spatial ($M = 1.31\%$, $SD = 11.3\%$) configuration in the low condition ($t_{38} = -0.161$, $p = 0.873$, $d = -0.026$) (See Figure 3).

RESULTS SUMMARY AND DISCUSSION

When given a choice of goals (e.g. picture A or picture B), do participants copy the choice of another agent (goal hypothesis) or do they copy the type of movement made by the other agent (movement hypothesis)? This was the primary question tested by Experiment 1. We found that participants' tendency to make the same (topographical) movement as a virtual character resulted in a change in the choices they had previously made in private thus supporting the movement hypothesis. In the anatomical condition, participants shifted their choices towards those of the virtual character as making the same movement as the virtual character meant making the same choice as her. In the spatial condition, participants shifted their choices away from those of the virtual character as making the same movement as the virtual character meant making a different choice to her. This supports the movement hypothesis rather than the goal hypothesis.

Do the kinematic properties of another agent’s movement, specifically the height of their point trajectory, influence people’s tendency to copy their movements and choices? This was the second question tested in Experiment 1. We found that participants’ tendency to imitate the type of movement made by the virtual character was driven by the observation of pointing movements with a high trajectory. Together these results suggest that our choices are not only influenced by other people’s choices but also the types of movements others make to indicate those choices.

EXPERIMENT 2

In Experiment 1 participants copied the movements of the virtual character and this changed the choices they had previously made in private. This tendency to imitate the virtual character’s movements was modulated by the kinematic features of her movement - participants copied the movement of the virtual character more when she pointed with a high, but not a low, trajectory. People who receive a diagnosis of autism spectrum conditions (from herein *autism*) show differences in their everyday social behaviours (American Psychiatric Association, 2013). There has been a long debate whether autistic people show differences in their copying behaviours (Dapretto et al., 2006; Southgate & Hamilton, 2008). The aim of Experiment 2 was to replicate Experiment 1 with a sample of autistic participants and a matched neurotypical sample to explore these potential differences. First, we briefly review studies of imitation in autism to motivate our hypotheses.

Goal-directed imitation in autism

Studies investigating social influence suggest that the basic mechanisms of social influence are intact in autism, for example, autistic participants rate objects which are the goal of someone’s action as more desirable than objects which are not the goal of their action (Forgeot D’Arc et al., 2016). This focus on other’s goals in autism is supported by the imitation literature. Autistic people are more goal-focused when copying others but imitate the means with which a goal was achieved to a lesser extent than non-autistic people. For example, Hamilton, Brindley and Frith (Hamilton, Brindley, & Frith, 2007) used the ear touching paradigm (Bekkering et al., 2000) to show that autistic children made the same types of errors and at the same frequency as their non-autistic peers suggesting intact goal-directed imitation in autism. Moreover, Hobson & Lee (1999) found that autistic participants were proficient in copying goal-directed actions, but tended not to copy the style with which the experimenter executed those actions. Similarly, Wild et al. (2012) showed that whilst non-autistic adults’ own movements were sensitive to the movement speed of another agent’s pointing movements, autistic adults’ movements were not modulated by the agent’s movement speed. Autistic participants also displayed more goal-directed eye-movements (Wild et al., 2012). These findings were supported by Forbes, Pan and Hamilton (Forbes et al., 2016) who showed that autistic and neurotypical participants showed no differences in their ability to copy the goal of a virtual character’s action, but autistic participants copied the kinematics of her action to a lesser extent. These results in adults are consistent with the developmental literature which show that autistic children do not overimitate (Marsh, Pearson, Ropar, & Hamilton, 2013).

However, what happens to goal-directed imitation when autistic participants have a choice of goals as was the case in our current paradigm? If there is a focus on goals during imitation, rather than the types of movements made, then autistic participants should copy the goal of the virtual character’s action. Thus, we predicted there would be comparable shifts in their preferences (or lack thereof) in both the anatomical and spatial conditions. This was the first hypothesis tested in Experiment 2.

Social cues and imitation in autism

In Experiment 1 we found that participants copied the type of movement made by the virtual character more when she pointed with a high, compared to a low, movement trajectory. This maps on to a theory of mimicry, the social-top down response modulation (STORM) model, which states that people change their mimicry (i.e. their unconscious imitation) depending on social cues (Yin Wang & Hamilton, 2012). For example, eye-contact (Wang, Newport, & Hamilton, 2011) and emotional facial expressions (Rauchbauer, Majdandžić, Hummer, Windischberger, & Lamm, 2015) have all been shown to enhance mimicry responses.

Movements with a high or exaggerated movement trajectory may also function as social cues (Forbes & Hamilton, 2017; Gergely & Csibra, 2003). They are produced in contexts where people intend to send a social signal of cooperation (Vesper, Schmitz, Safra, Sebanz, & Knoblich, 2016), and observation of high trajectories activates ‘mentalising’ areas of the brain (Marsh, Mullett, Ropar, & Hamilton, 2014) . Similarly, caregivers often exaggerate components of an action sequence when interacting with an infant (Brand, Baldwin, & Ashburn, 2002) and it has been suggested that this “motionese” may help infants to establish what to imitate (Nagai & Rohlfing, 2007). Based on the results of Experiment 1, we suggest that the height of the movement performed by the virtual character acts as a social cue, in this case signalling ‘this one is important’. If neurotypical participants perceive and act on this social cue, this could drive their imitation of the virtual character.

Interpreting the results of Experiment 1 within the STORM model also leads to specific predictions for the performance of autistic participants. STORM predicts that there is less modulation of imitation by social cues in participants with autism. For example, eye-gaze (Forbes, Wang, & Hamilton, 2017; Vivanti & Dissanayake, 2014), prosocial priming (Cook & Bird, 2012), and emotional facial expressions (Grecucci et al., 2013) enhance imitative tendencies in non-autistic participants but not in autistic participants. Thus, according to STORM, autistic participants should not change their imitation behaviour based on the height of the virtual character's pointing movement as was found in Experiment 1. This was the second hypothesis we aimed to test in Experiment 2.

METHOD

Changes from Experiment 1

Methods for Experiment 1 were the same as Experiment 2 apart from the following changes:

Private task.

After the presentation of the pictures the question "Which picture do you prefer?" stayed on the screen until participants indicated their preference by pressing the appropriate key on the keyboard. This was done to prevent a loss of trials due to the participants not responding quickly enough as occurred in Experiment 1.

Design.

A between-subject factor, Group (neurotypical vs. autism), was added to the 2 (configuration: anatomical vs. spatial) x 2 (height: high vs. low) design.

Participants.

29 neurotypical and 27 autistic participants were recruited through the autism@icn participant database and came to the university as part of a research day during which they took part in multiple studies. We aimed for a sample of at least 25 participants in each group. The final sample size was determined by the availability of participants on the database during the testing period. Data analysis was not conducted until the end of data collection. Groups were matched on age, gender, handedness, and, verbal and performance IQ using either the Wechsler Adult Intelligence Scale (WAIS-III UK; Wechsler 1999a) or Wechsler Abbreviated Scale of Intelligence (WASI-II, Wechsler 1999b; Table 1). All autistic participants had a diagnosis of an autism spectrum disorder from an independent clinician: 20 participants had a diagnosis of Asperger's Syndrome and 7 participants had a diagnosis of autism spectrum disorder. Autistic participants were also tested on module 4 of the Autism Diagnostic Observation Schedule (ADOS-G Lord et al. 2000) or ADOS-2 (Lord et al. 2012) by a trained researcher with research-reliability status: ten met the ADOS classification for autism, ten for autism spectrum, and, seven did not meet the classification of autism or autism spectrum. However, all seven who did not meet the cut off for an overall classification of autism or autism spectrum, reached the ADOS cut-off for autism spectrum on either the communication or reciprocal social interaction subscale. Five autistic participants had additional diagnoses: dyslexia (1), dyspraxia (1), or ADHD (2), and, one participant had additional diagnoses of both ADHD and dyspraxia. All participants were financially reimbursed for their time and gave written informed consent to participate.

[insert Table 1 about here]

RESULTS

Excluded data

Failure to choose in the social task.

If participants failed to indicate their choice during the social task these trials were excluded from the analysis. This occurred on 1.38 % (2.07%) of trials for neurotypical participants and 2.36% (2.95%) for the autistic participants. There were no significant differences between the number of excluded trials between the groups ($t_{54} = -1.45$, $p = .16$, $d = 0.38$).

Shift in choice

Consistency.

In the social setting neurotypical participants stuck with their choice from the private setting on 76.72% (7.78%) of trials and autistic participants stuck with their choice on 58.81% (6.08%) of trials. An independent samples t-test revealed that neurotypical participants were more consistent in their choices than autistic participants, $t_{54} = -9.55$, $p < .001$, $d = 2.63$. Autistic participants reported having visited art galleries less often in the past 12 months (see Table 2) and Experiment 1 found that gallery visits was significantly correlated with consistency. Thus, we conducted a multiple linear regression to explore whether consistency was better predicted by reduced art experience or an autism diagnosis. The model explained 62.9% of the variability in consistency, $R^2 = .63$, $F_{2,53} = 44.84$, $p < .001$. When holding the number of art visits in the past 12 months constant, group significantly predicted consistency, $\beta = .79$, $t_{53} = 8.96$, $p < .001$. When controlling for group, art visits did not significantly predict consistency, $\beta = -.02$, $t_{53} = -0.28$, $p = .78$.

Preference shift.

Shift was calculated as in Experiment 1. A one sample t-test ($t_{55} = 0.182$, $p = 0.856$) revealed that mean shift scores did not differ significantly from 0 showing that overall participants did not shift their choices towards or away from those of the virtual character from the private to the social setting. To explore differences across the conditions we conducted a 2 (configuration: anatomical vs. spatial) x 2 (height: high vs. low) within-subjects ANOVA on the shift scores. We first report the ANOVAs for each group separately, before reporting the 2 x 2 x 2 ANOVA with group (neurotypical vs. autism) as a between-subject factor.

Neurotypical.

Neurotypical participants displayed a main effect of configuration ($F_{1,28} = 7.82$, $p = 0.009$, $\eta_p^2 = 0.218$) with mean shift scores greater in the anatomical condition, 1.75% (*SD* = 6.33%), compared to the spatial condition, -2.89% (*SD* = 7.32%) (see Figure 4). The main effect of height ($F_{1,28} = 1.76$, $p = 0.195$, $\eta_p^2 = 0.059$) and the interaction between configuration and height were not significant ($F_{1,28} = .371$, $p = 0.548$, $\eta_p^2 = 0.013$).

Autism.

Autistic participants did not display a main effect of configuration ($F_{1,26} = .957$, $p = .337$, $\eta_p^2 = .036$) or height ($F_{1,26} = .429$, $p = .518$, $\eta_p^2 = .016$) and there was no significant interaction between configuration and height ($F_{1,26} = .001$, $p = .976$, $\eta_p^2 < .001$)**.**

Group comparison.

By including group as a between-subject factor, this revealed a main effect of configuration ($F_{1,54} = 6.69$, $p = .012$, $\eta_p^2 = .110$) with mean shift scores greater in the anatomical condition, 1.79% (*SD* = 6.78%), compared to the spatial condition, -1.50% (*SD* = 7.04%). No other main effects or interactions were significant.

RESULT SUMMARY AND DISCUSSION

Experiment 2 aimed to replicate the findings from Experiment 1 and explore any differences in autistic participants. Experiment 2 replicated Experiment 1 by demonstrating that participants’ tendency to make the same (topographical) movement as a virtual character resulted in a change in the choices they had previously made in private. This suggests that when given a choice of goals participants are more likely to copy the type of movement made by another agent rather than the action goal. In the anatomical condition participants shifted their preferences towards those of the virtual character as making the same movement as the virtual character also meant making the same choice as her. In the spatial condition participants shifted their preferences away from those of the virtual character as making the same movement as the virtual character meant making a different choice to her. When we controlled for copresence - the extent to which participants felt immersed in the virtual social interaction - we replicated the second finding from Experiment 1 - the tendency to make the same movement as the virtual character was driven by the observation of pointing movements with a high trajectory. Finally, we found no evidence of any significant differences in the autism sample, except that autistic participants were less consistent in their choices between the private and social setting.

GENERAL DISCUSSION

Across two studies and 95 participants, we demonstrated that participants showed a consistent tendency to copy the (topographical) movements made by a virtual character rather than the goal of her action. This resulted in a change in the choices participants had previously made in private. In the anatomical condition, participants shifted their preferences towards those of the virtual character as making the same movement as the virtual character meant making the same choice as her. In the spatial condition, participants shifted their preferences away from those of the virtual character as making the same movement as the virtual character meant making a different choice to her. In Experiment 1, we showed that this tendency to copy the virtual character’s movements was modulated by the kinematics of her pointing trajectory - participants copied her movements more when she pointed with a high, but not a low, trajectory. But this effect of height may be fragile as we did not replicate it in Experiment 2. The results of the autistic participants were ambiguous: unlike neurotypical participant, autistic participants did not display a main effect of configuration. However, we did not find any significant group differences in the imitation behaviour.

The results suggest that when we have a choice of goals, as is common in many everyday social situations, imitation may be driven by others' movements rather than their action goals. More generally, these findings suggest that when we make choices in the presence of others, our choices are not only influenced by other people's choices but also the types of movement others make to indicate their choices. We discuss our findings in terms of theories of imitation.

Copying topographical movements rather than action goals

In contrast to many studies investigating imitation, the current study gave participants a choice of goal (e.g. picture A or picture B). Arguably, this is much more akin to how imitation operates in everyday social interactions. For example, at a restaurant you are not obliged to copy the choice of your friend - you have a choice. Theories of imitation, such as GOADI (Wohlschläger et al., 2003), have mainly been tested under conditions where there is a clear, unambiguous goal or no goal at all (Bekkering et al., 2000; Wild et al., 2010, 2012). When the goal is clear, participants prioritise imitating the goal at the expense of the way in which the goal was achieved, such as the particular movement made to point to a target. Our findings suggest, however, that when the imitator has a choice of goal, the types of movements others make to indicate their choices plays a more important role in imitation.

We showed that participants show an imitative advantage when there is a topographical (i.e. anatomical) matching between the movement of a model and that of an imitator. Here, the participants can map the actions of another agent onto their own body (Tsakiris, 2010). This supports previous work comparing anatomical and spatial imitation

(Pan & Hamilton, 2015; Ramenzoni et al., 2015). Both Pan and Hamilton (2015) and Ramenzoni et al. (2015) used reaction time measures of imitation - the time taken to tap the first drum in a sequence and tapping asynchrony, respectively. The present findings build on this work by showing that participants made the same anatomical movement as another agent with a greater frequency. This imitative advantage seen for anatomical movements can be explained by associative accounts of imitation, such as Heyes' associative sequence learning (ASL) account (Heyes, 2011).

According to Heyes, when we consistently observe an action and perform an action contingently, overtime, the connections between the visual representation and motor representation involved in observing and performing this action become strengthened. Thus, if we observe a particular action, we are primed to make a movement which has been associated with that action. In terms of the current paradigm, ASL rests on the assumption that we have greater experience of observing and executing anatomically matched pointing movements rather than those matched spatially. Thus, following the observation of a pointing movement we are primed to make a pointing movement which matches this movement anatomically. Gillmeister et al. (2008) showed that through sensorimotor training it is possible to change these anatomically matched associations (Gillmeister, Catmur, Liepelt, Brass, & Heyes, 2008). Thus, future studies using the current paradigm could train participants to observe and execute spatially matched, rather than anatomically matched, pointing movements to see if this alters participants' preference shifts.

Our findings fit with the literature on cross-contextual imitation where participants imitate an observed movement (e.g. lifting) even then the model has a different goal (e.g. lifting barbell) to that of the participant (e.g. lifting a cup for drinking) (Genschow & Florack, 2014; Genschow, Florack, & Wänke, 2013). Together with our findings, this suggests that copying the goal of an action may not be always be a necessary precondition for imitation.

Interesting, cross-contextual imitation is modulated by social cues, such as group membership (Genschow & Schindler, 2016), so it would be of interest to explore these moderators in our paradigm.

Modulating imitation through actor kinematics

Experiment 1 showed that participants were more likely to imitate the anatomical rather than spatial movement of the virtual character if she pointed with a high, but not a low, trajectory. Thus, participants' propensity to imitate the virtual character was modulated by the kinematics of her pointing movement. This is in line with Wang and Hamilton's (2012) model of mimicry, STORM, which predicted that all mimicry is subject to top-down modulation by a range of social cues (Wang & Hamilton, 2012). Our data shows that high or exaggerated movement trajectories, which have a communicative function (Cleret de Langavant et al., 2011; Peeters et al., 2013), appear to modulate imitative tendencies in a similar way to other social cues, such as eye-gaze (Forbes & Hamilton, 2017; Wang, Ramsey, & Hamilton, 2011), social priming (Cook & Bird, 2012), and emotional facial expressions (Grecucci et al., 2013). This is supported by neuroimaging studies which show that high movement trajectories preferentially activate the brain's mentalising system, such as medial prefrontal cortex (Marsh et al., 2014). This same region has been implicated in controlling the social modulation of mimicry by direct gaze (Wang, Ramsey, & Hamilton, 2011). Thus, high movement trajectories may modulate imitative tendencies via the same neurocognitive mechanism as other social cues, such as direct gaze. Future neuroimaging studies are needed to confirm this.

While the current study manipulated the height of the pointing movement, other kinematic features of pointing movements could modulate imitation in a similar way. For example, Patel et al. (2012) showed that when participants observed another agent make a movement more quickly, then they rated their decision as more confident. Thus, future work should explore whether pointing movements with certain velocities are more readily imitated. Further studies are also needed to investigate the robustness of the effect of height as we did not replicate it in Experiment 2.

Imitation and autism

Experiment 2 had two hypotheses concerning the imitation behaviour of autistic participants. Firstly, previous work has suggested that autistic participants are more goal-focused during imitation (Marsh et al., 2013; Wild et al., 2012). We predicted therefore that there would be comparable shifts in preferences (or lack thereof) in both the anatomical and spatial conditions for autistic participants. Autistic participants showed a smaller difference between configuration conditions compared to the neurotypical group and unlike the neurotypical group this difference was not statistically significant (Figure 4). . However, there were no significant differences in imitation behaviour between the groups (i.e. no significant configuration x group interaction). Thus, when given a choice of goals, we found no evidence for increased goal-directed imitation in autism. Yet, given the ambiguity of our results, future studies, ideally with larger sample, will be needed to confirm this. Secondly, we predicted that autistic participants would not change their imitation behaviour based on the height of the virtual character's pointing movement, as was found in Experiment 1. As, according to STORM, the modulation of imitative tendencies is different in autism (Wang and Hamilton, 2012). Again, we found no evidence to support this prediction. Thus, the implications of our findings for theories of imitation in autism remain equivocal. It is important to note, however, that most studies which have found differences in the social modulation of imitation and mimicry in autism have used reaction times measures of mimicry (Cook & Bird, 2012; Forbes et al., 2017; Grecucci et al., 2013). It has recently been demonstrated that different measures of imitation and mimicry are poorly related to one another (Genschow et al., 2017). So, when detecting differences in mimicry and imitation in autistic samples, the type of mimicry measure used may be critical. For example, a recent meta-analysis found no evidence of automatic imitation differences in autism (Cracco et al., 2018).

One unexpected finding from Experiment 2 was that autistic participant were less consistent in their choices between the private and social setting. Neurotypical participants stuck with their choices from the private setting on 78% (Experiment 1) and 77% (Experiment 2) of trials in the social setting. Autistic participants stuck with their choices on 59% of trials and the analysis revealed that this reduced consistency could not be explained by the greater interest in art in the neurotypical group (as indexed by the number of gallery visits in the past 12 months). The finding that autistic participants changed their choices more from the private to the social setting seems at odds with one of the core features of autism - restricted and repetitive behaviours (American Psychiatric Association, 2013). Although an insistence on sameness has been widely reported in autistic individuals (American Psychiatric Association, 2013), the lack of consistency in the choices of autistic participants in our task may be due to differences in executive functioning and attentional processing (Happé, Booth, Charlton, & Hughes, 2006). Moreover, increasing evidence suggests that differences in experimental and neuropsychological measures of cognitive flexibility are poorly related to everyday restricted and repetitive behaviours (Geurts, Corbett, & Solomon, 2009; Teunisse et al., 2012).

Future directions

Although participants changed some of their choices from the private to the social setting, it is not clear whether this resulted in an actual shift in their art preferences. For example, if participants chose picture A in the private setting but then chose picture B in the social setting, did they actually prefer picture B? Or, alternatively, was this simply a transient change in choice driven by the observation of the virtual character's movements? For example, participants change their ratings of music when exposed to the opinions of others (Campbell-Meiklejohn et al., 2010) and Izuma and Adolphs (2013) found that participants preferences for t-shirt designs remained influenced by the opinions of others even after 4 months. Yet, Huang, Kendrick and Yu (2014) found that people's ratings of facial attractiveness were influenced by the ratings of others for up to three days but not longer than seven days. Thus, future work using the current paradigm will need to establish whether any changes in participants' choices persist or are transient.

Participants changed their choice on approximately one in every four or five picture pairs and when participants did change their choices they were influenced by the virtual character's movements. However, the choices participants made in the current study did not have any significant consequences. Copying the movements of others has been shown to override strong financial incentives to avoid imitation during competitive games (Belot, Crawford, Heyes, & Scheinkman, 2013; Naber, Vaziri Pashkam, & Nakayama, 2013). So, had participants been incentivised to be consistent in their choices between the private and social setting, would the influence of virtual character's movements have had comparable effects on their choices? Alternatively, if participants have particularly strong preferences for certain types of stimuli (e.g. a choice between two foods), would we see the same effects of movement imitation or would preferences be a better predictor of participants' behaviour? These questions remain to be tested in future studies.

An additional avenue for future research is to increase the communicativeness of the task. For example, the paradigm could include gaze following so that the virtual character responds to the hand and/or eye movements of the participants. This will allow us to establish whether the increased social engagement of the virtual character will result in differences in imitation behaviour (Forbes et al., 2016; Hamilton & Lind, 2016)

Conclusion

Theories of imitation have stressed that we prioritise copying the goals of observed actions (Bekkering et al., 2000; Wohlschläger et al., 2003) and that social influences are driven by our observation of others' choices (Campbell-Meiklejohn et al., 2010). However, most experiments which have tested these theories have failed to include conditions in which participants have a choice of goal. Across two experiments we showed that when neurotypical participants were given a choice of goal, they tended to imitate the topographical movement made by a virtual character rather than her choice. There were no significant differences between the imitative behaviour of neurotypical and autistic participants, despite autistic participants showing a reduced imitation effect. In Experiment 1 we found that the tendency to copy the virtual character's movements was driven by the observation of the virtual character's high pointing movements, although we did not replicate this finding in Experiment 2. These findings tentatively support the STORM model by demonstrating that imitative tendencies can be modulated by subtle social cues, such as the kinematics of an actor's movements (Wang & Hamilton, 2012). More generally, we show that the way others move can influence what we choose.

FIGURES

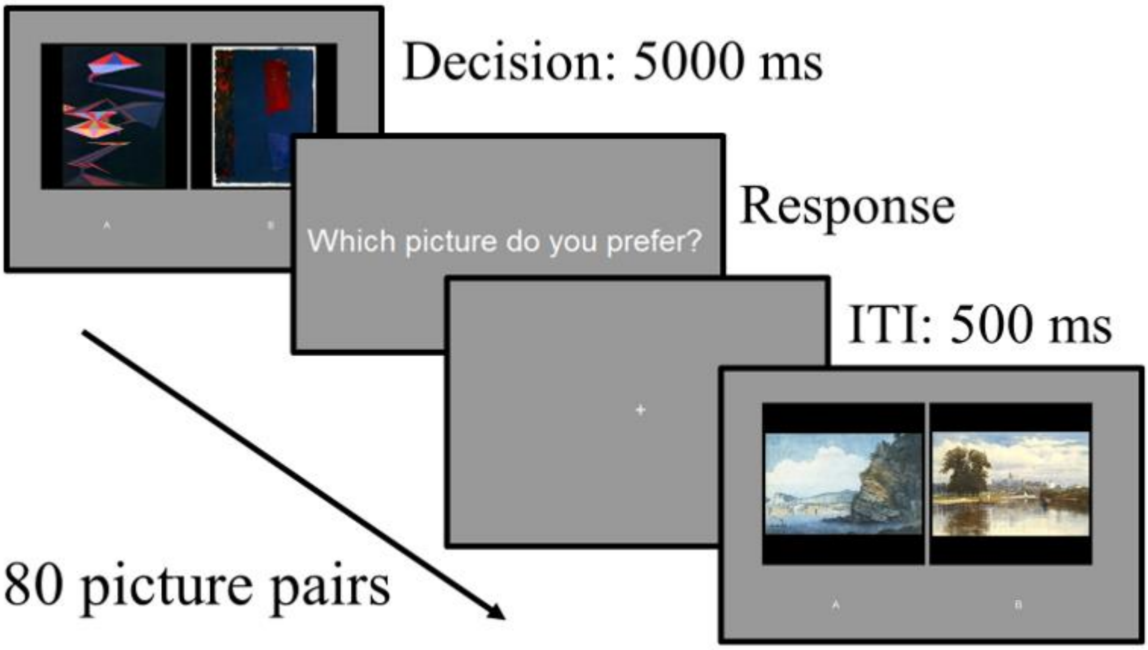

Figure 1. The private task trial structure.

In Experiment 1 participants had 2 seconds to respond to indicate their preference during the response period. As some participants did not respond within 2 seconds in Experiment 1, this response period was unlimited in Experiment 2. ITI = inter-trial interval.

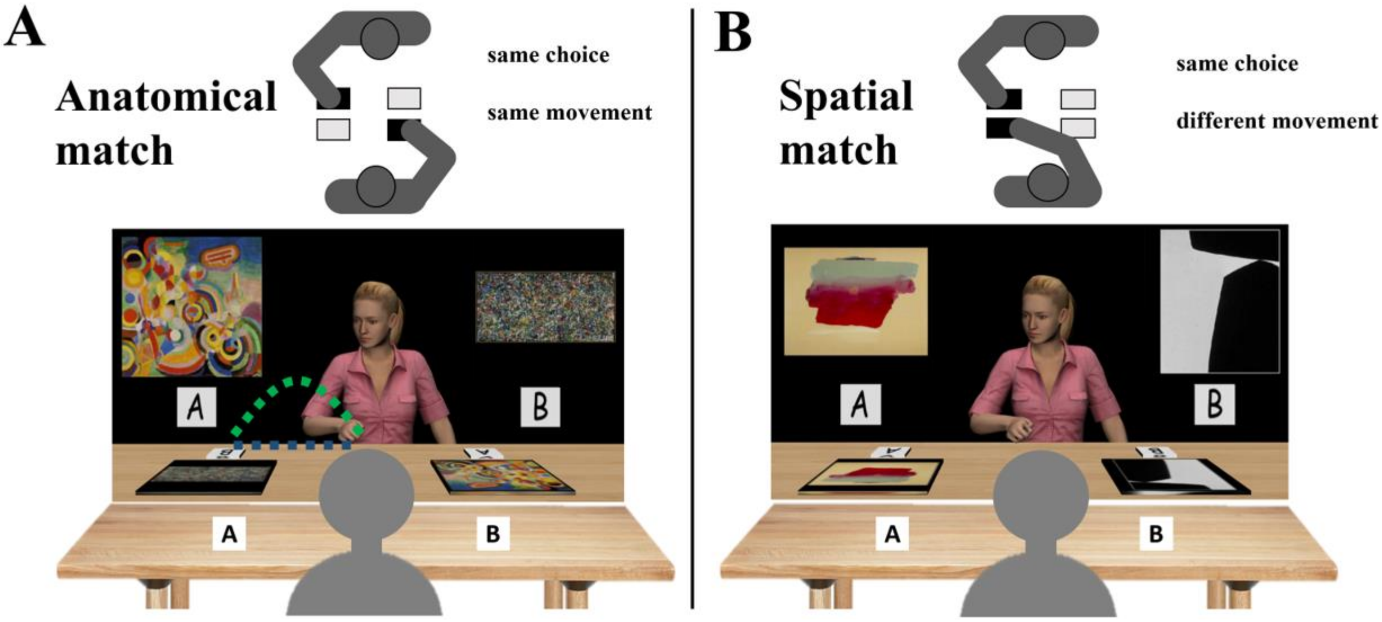

Figure 2. The social task setup.

Participants sat opposite the virtual character and she pointed to indicate her preference with either a low (blue) or high (green) movement trajectory. In each block there was either an anatomical (A) or spatial (B) match between the virtual character's pictures and those of the participant. Participants movements were considered an anatomical match (A) if both moved contralaterally (as shown in A) or if both move ipsilaterally. In the anatomical condition (A), pictures were arranged so that anatomically matching movements allowed both to point to the same picture. In the spatial condition, if participant made the same choice as the virtual character then they had to make a different movement – in this case one makes an ipsilateral movement and the other a contralateral movement

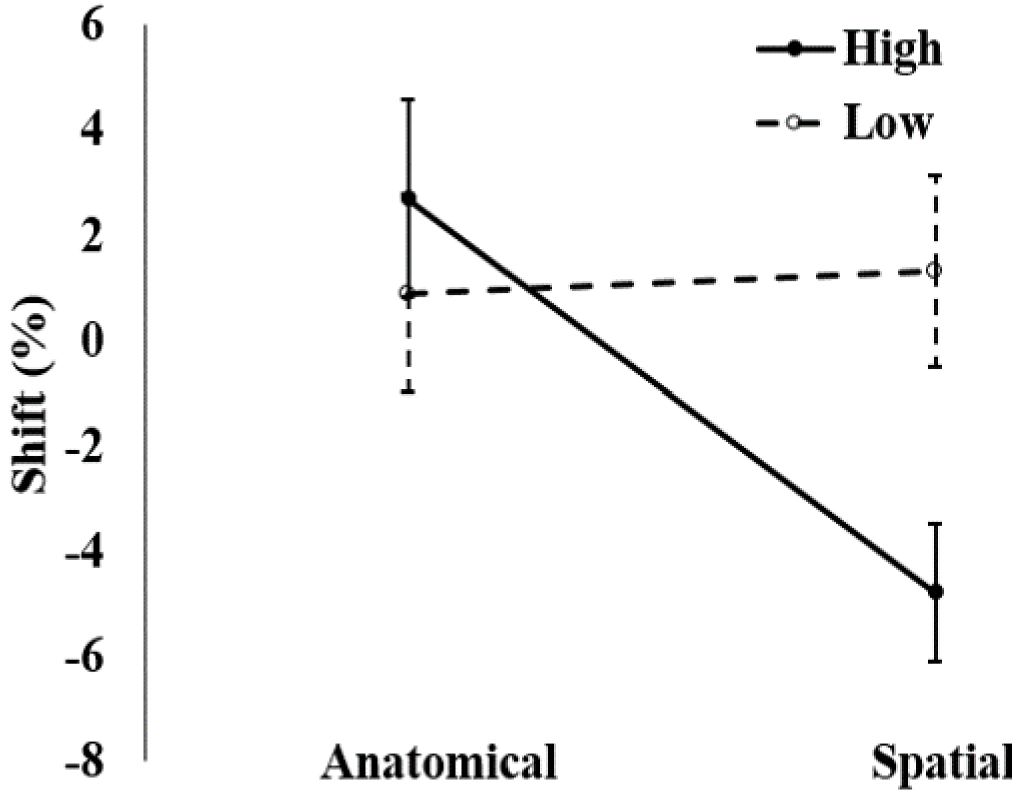

Figure 3. Mean shift scores in Experiment 1. Errors bars indicate standard error

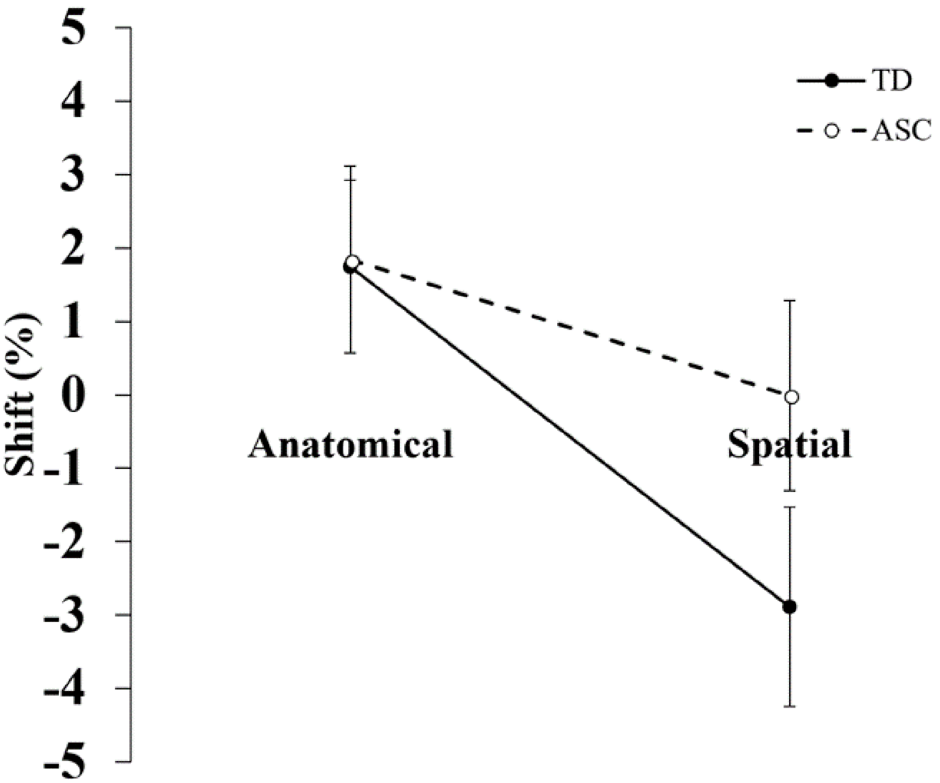

Figure 4. Mean shift scores for the autistic and neurotypical participants in Experiment 2. Errors bars indicate standard error

TABLES

Table 1. A comparison of the autistic and neurotypical participants

	Neurotypical ($n = 29$)		Autistic ($n = 27$)		*t* test
	Mean (*SD*)	Range	Mean (*SD*)	Range	*p* value
Age (years)	31 (11)	19-61	32 (8)	20-53	0.59
Full IQ	117 (12)	87-138	117 (14)	86-152	0.75
Verbal IQ	117 (13)	88-147	119 (14)	91-155	0.46
Performance IQ	113 (15)	76-146	110 (15)	80-132	0.94
AQ	14 (7)	3-28	33 (9)	12-48	< .001
ADOS: total	-	-	9 (3)	4-17	-
ADOS: comm.	-	-	3 (2)	0-6	-
ADOS: RSI	-	-	6 (2)	2-11	-
Gender	20 M; 9 F	-	22 M; 5 F	-	-
Handedness	26 R; 3 L	-	24 R; 3 L	-	-

Table 2. A comparison of co-presence, interest in art and art gallery visits in the past 12 months between the two groups (NT: neurotypical; ASC: autism)

	NT (*n* = 29)	ASC (*n* = 27)	*t* test		
	Mean (*SD*)	Mean (*SD*)	t_{54}	*p*	*d*
Co-presence	2.95 (1.37)	3.04 (1.45)	-0.26	.80	.06
Art Interest	5.03 (1.30)	4.70 (1.68)	0.83	.41	.21
Art Visits*	4.70 (2.88)	2.96 (2.75)	2.29	.03	.62

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