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How preference towards robotic agents affects choice accuracy in children with Autism Spectrum Disorder

Abstract—This study investigates the effects of non-verbal socio-affective feedback provided by two different virtual agents (i.e. a human and a humanoid robot) on the performance of children with Autism Spectrum Disorder (ASD), in a decision-making task. The task, inspired by the “Shell Game”, required participants (N = 29, Mean age = 6.5 years) to guess which cup out of two was hiding a ball. After participants made their choice, the virtual agents provided either positive, negative, or no feedback. Results indicated no significant effects on response times (RTs) but revealed a main effect of virtual agent type on accuracy, with participants performing less accurately when playing with the robot virtual agent compared to the human virtual agent. Furthermore, participants' preference for the robot virtual agent was associated with lower accuracy. No significant effects were found on feedback presence. These findings suggest that the preference for the robot virtual agent may have distracted some children, leading to decreased accuracy during the task. Attentional focus on the virtual agent during the cue presentation may have influenced performance but not overall cognitive processing speed. Understanding individual preferences and potential distractions using virtual agents can help optimize the development of interventions for children with ASD.

Keywords—*Robotic agents, Virtual agents, Autism Spectrum Disorder*

I. INTRODUCTION

One of the characteristics of Autism Spectrum Disorder (ASD) is difficulties in social communication and interaction [1], which can express itself as misinterpretations of, or atypical responses to, non-verbal social cues. For example, it has been found that individuals with ASD find non-verbal social cues to have less intrinsic value than typically developing (TD) individuals [2-4]. Furthermore, individuals with ASD have shown atypical detection of non-verbal social cues such as eye-gaze (see [5] for a review), facial expressions [6] or gestures [7]. Generally, in comparison to TD individuals, individuals with ASD appear to be less affected by non-verbal social cues when they are involved in a gaze-cueing task [8, 9].

Another characteristic of ASD is the presence of restricted, repetitive patterns of behaviours, interests or activities [1]. For example, individuals with ASD frequently exhibit a heightened interest in “systems” [10], such as mechanical artefacts. One sub-category of mechanical artefacts that some individuals with ASD find intrinsically interesting is technology. For example, research has found that some children with ASD appear to have an intrinsic interest in artificial agents, such as robots [11 – 15]. Furthermore, some studies suggest that some individuals with ASD find

interactions with artificial and robotic agents more rewarding than interactions with humans [16, 17].

Researchers have begun to leverage this interest in technology in interventions for children with ASD to target development of social skills [18], communication training [19] and learning [20]. One such technological solution that has an advantage is virtual agents (either 2D or 3D) as they can be easily customizable and accessible through various digital platforms. They can also be designed to exhibit gestures and expressions, making them effective tools for teaching social behavior and interaction [21]. Furthermore, the initial findings using virtual agents in social skill development with children with ASD have been promising. For example, some studies with children with ASD have found that robotic virtual agents can facilitate joint attention [22, 23] and eye gaze [24, 25].

One particular way in which virtual agents could facilitate learning is by using them to provide non-verbal feedback, which varies in valence (i.e., positive or negative). The integration of feedback can help to promote desirable behavior, and in some cases modify behaviour. Indeed, elements of feedback have already been integrated into some research using artificial agents to enhance social learning in children with ASD [22, 26, 27]. For example, studies have used virtual agents to provide feedback on nonverbal and verbal behavior during various learning activities such as communication skills training [20, 19, 28]. Moreover, virtual agents and virtual peers seem to engage children with ASD and improve their motivation to participate in training activities [29].

While initial findings appear to support the use of virtual agents in interventions for individuals with ASD, it is still unclear how the appearance of these virtual agents affects participants' performance and subjective impressions [30, 31]. Individuals' specific interests and biases could have a moderating effect on the outcome of the virtual agent intervention or exposure. For instance, based on the restricted interests' literature we would expect that a virtual agent that looks like a robot would be more engaging than a virtual agent that looks like a human [16, 17]. On the other hand, the human-like form can allow virtual agents to exhibit realistic non-verbal human-like gestures which is thought to enhance their effectiveness in teaching social behaviour [32].

Since various studies have shown the potential of virtual agents to positively influence the behavior of individuals with ASD, we created a task to investigate the effect of feedback from virtual agents on performance. This task measures performance using response times and accuracy. Response

times and accuracy can provide an implicit measure of the impact of receiving social cues (i.e. feedback from a virtual agent) during a task. These behavioral measures can also be used to assess the effectiveness of interventions and track participants' progress over time. Moreover, these measures can provide insight into cognitive processes that are not accessible through questionnaire or interview data. For instance, reaction times are widely used in cueing tasks as a marker of attentional focus [33, 34]. Behavioral implicit measures can also reveal underlying biases and preferences [35].

II. AIMS

In this paper, we implemented a decision-making task with a within-subjects design where we manipulated the type of virtual agent and the agent's feedback. Our goal was to (i) examine the effects of these social signals (type of agent and feedback) on participants' performance and their potential interaction, and (ii) to assess participants' preference toward a specific virtual agent. The task was a cups-and-ball game in which participants had to find which of the two presented cups was covering a ball. Participants received a cue that indicated which cup was hiding the ball (e.g. cup becoming green for 100 ms) before they made their choice. After participants made their choice, the agent (a humanoid robot 'iCub,' and a human avatar) either gave positive, negative or no feedback. Because feedback could be a salient stimulus in interaction, we hypothesized that participants would be more accurate in the blocks in which they received feedback from the agent (H1), relative to no feedback. We also expected participants to be more accurate when playing with the robotic agent given the preference towards robotic and technological products in ASD [10] (H2). Finally, we expected participants to prefer the robotic virtual agent compared to the human-like virtual agent in qualitative data (responses to questions at the end of the experimental session).

III. METHODS

A. Participants

We recruited 29 children at the rehabilitation centre [name of the institution removed for anonymization purpose]. The healthcare professionals of the centre collected informed consent by parents or legal representatives of children participating in the study. Parents and legal representatives were informed about the design, procedure and aim of the study. The experiment was conducted under the ethical standards (Declaration of Helsinki, 1964) and approved by the local Ethical Committee ([name of committee removed for anonymization purpose]). Collected data were anonymized using ID number automatically generated by an ad-hoc Python program (see Apparatus section) for each participant. All children received the diagnosis of ASD from the National Health Care System ([name of the institution removed for anonymization purpose]). The average age was

6.5 years (sd = 1.5 years) and the average Griffiths' IQ was 70 (sd = 16.9).

B. Procedure

Participants were asked to sit in front of the computer and the health professional would give instructions on how to play. Two buttons were placed between the computer and the participants. Participants were asked to complete the task with the option of taking breaks between blocks. The experimental setting is depicted in Figure 1.

After completion of the task, the health professional asked the participant whether they would like to play the game again in the future and which virtual agent they preferred. Participants could answer freely while the professionals were writing the answers. The health professional, instructed to support data collection and give instructions to participants, were naïve to the study aim and hypothesis to prevent data collection biases.

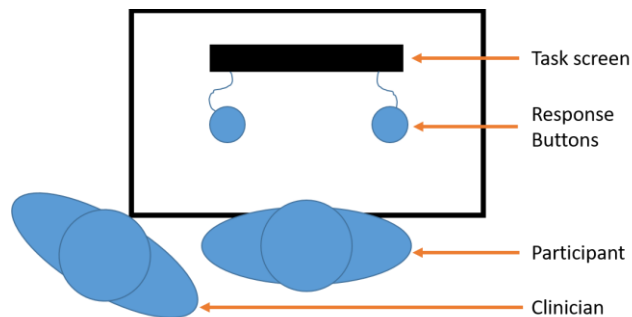


Figure 1. Experimental setting.

C. Apparatus

Participants sat in front of a 22" LCD monitor. The first screen displayed the virtual environment for the decision task which was run on a computer with an AMD Ryzen Threadripper 2950X 16-core 3.5 GHz CPU, 128 GB of RAM and a NVIDIA GeForce GTX 1060 3 GB video card. The 3D-animated virtual environment including avatars with the appearance of the iCub robot [36] was developed using Unreal Engine (Epic Games: www.unrealengine.com). An ad-hoc Python program (version 3.9.5) handled stimulus presentation and data collection. A similar procedure was used in a work with neurotypical participants [31]. Participants responded by pressing one of the two buttons (left and right respectively) connected to a response box which was connected to the computer. The response box and buttons were developed and produced by the engineering laboratory of the authors' institution [name of the institution removed for anonymization purpose].

D. Task

The task was loosely inspired by the Shell Game. The game requires the game partner (here the virtual agent) and the participant to guess the position of a ball hidden under one of two presented cups. We presented the participants with a screen-based virtual setting in which two cups were located on a table and an agent was positioned on the other side of the table. Instructions stated that the ball could change

position on each trial and that the agent would be guessing together with the participant. We asked participants to be as accurate as possible in finding the correct location of the ball. The game started with the virtual agent looking at the participant, and then a cue would appear to hint the hidden ball position to participants. The cue consisted in one of the two cups changing color for 100 ms from red to green (see Figure 1. “cue section”). The cue was always hinting correctly toward the cup under which the ball was hidden. An exogenous and consistently congruent cue was selected throughout this task to ensure that participants did not perceive any unfair advantage from the robot or environment, allowing for a reliable assessment of the impact of variables of interest (social signals) on performance.

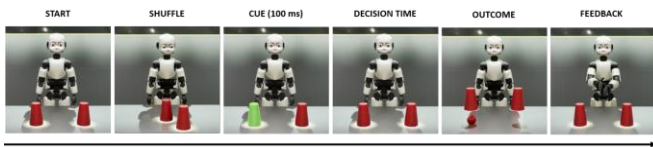


Figure 2. Trial structure.

After the cue, participants were able to make their decision by pressing the left button to select the left cup and the right button to select the right cup. After the button press, both cups lifted to show the ball position. After the cups lifted, the virtual agent gave participants positive feedback if they chose the cup that hid the ball and negative feedback if they chose the cup without the ball underneath. The positive feedback consisted of the virtual agent producing a happy facial expression, clapping hands and nodding. The negative feedback consisted of the virtual agent showing a sad facial expression, taking its hand to the head while shaking its head. Feedback behaviors used in this study have been previously validated [ref hidden for anonymization purpose] and can be found under the link: (link hidden for anonymization purpose). After the feedback, the next trial would start. To check the effect of robot appearance on participants’ performance and likability, we controlled for the type of motion of the virtual agents. Both the virtual agents (iCub or human appearance, see Figure 3), were showing human-like gestures and idle movements inspired by biological motion and animations studies [37, 38].

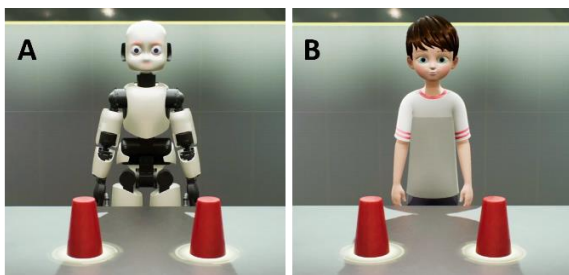


Figure 3. Virtual agents’ appearance: A) Robot-like agent inspired by iCub Robot. B) Human-like agent inspired by iCub features.

The task consisted of 4 blocks containing 10 trials each. In each block, the trial sequence was controlled so that the

probability of the ball being on one side was always 50%. The four blocks were: human virtual agent producing feedback, human virtual agent not producing any feedback, robot virtual agent producing feedback and robot virtual agent not producing feedback. The block order was randomized across participants. During the task, behavioral measures (response times and keypress) were collected.

E. Qualitative Measures

At the end of the task participants were asked whether they would play the game again and which virtual agent they preferred. Answers were collected by the health professionals at the host institution. To facilitate the discussion of the results, the answer to the question “would you play again this game” is defined as *likeability*. The second question was defined as *virtual agent preference*.

F. Data Analysis

We excluded the trials in which participants were faster than 100 ms (5%) from the analyses [39]. Trials in which RTs were slower than 2.5 standard deviations than the sample mean were considered outliers and were removed from the final analyses (6%). Accuracy was defined by how many times participants chose the cup hinted by the cue (i.e. the cup with the hidden ball). As such, accuracy represents the ability of the participant to learn the cue validity and pay attention to it, in order to complete the task. Accuracy and RTs were separately submitted to a linear mixed model as dependent variables. Each model included presence of feedback and type of virtual agent as fixed effect variables and participant ID as a random effect grouping factor. RTs were also submitted to a linear mixed model as a dependent variable to investigate differences between correct and incorrect trials. Frequencies regarding the answers to the final questions were extracted. P-values for post hoc analyses were corrected for multiple comparisons via Tukey method. Descriptive statistics were extracted for all the above-mentioned measures. All the analyses were conducted in R Studio and plots created through ggplot2 package.

IV. RESULTS

A. Response times and accuracy

RTs and accuracy were separately submitted to a linear mixed model with presence of feedback (feedback vs no feedback) and type of virtual agent (iCub vs human) as two levels fixed effects. Participants ID was included as a random effect in the model.

Results associated to RTs showed no effect related to type of virtual agent ($\beta_{estimate} = 0.022, t(1,634) = 0.146, p = 0.884$), presence of feedback ($\beta_{estimate} = -0.133, t(43) = -1.015, p = 0.31$) or interaction between these two factors ($\beta_{estimate} = 0.061, t(43) = 0.302, p = 0.763$). We also analyzed RTs by submitting the data to a linear mixed model with accuracy (correct vs incorrect trials) as a two levels fixed effect and participants ID as a random effect. The model showed no significant difference ($\beta_{estimate} = -0.16, t(1,634) = -1.14, p = 0.255$)

Results related to accuracy revealed a main effect of type of virtual agent ($\beta_{estimate} = 0.145$, $t(1,634) = 3.516$, $p < 0.001$) where accuracy while playing with the iCub virtual agent ($M = 0.794$) was significantly lower than in the human virtual agent condition ($M = 0.889$) (see Figure 4). No effect was found related to presence of feedback ($\beta_{estimate} = 0.036$, $t(1,634) = 0.977$, $p = 0.329$) and no interaction ($\beta_{estimate} = -0.071$, $t(1,634) = -1.252$, $p = 0.211$). Considering the entire experimental session, average accuracy of the sample was 86%.

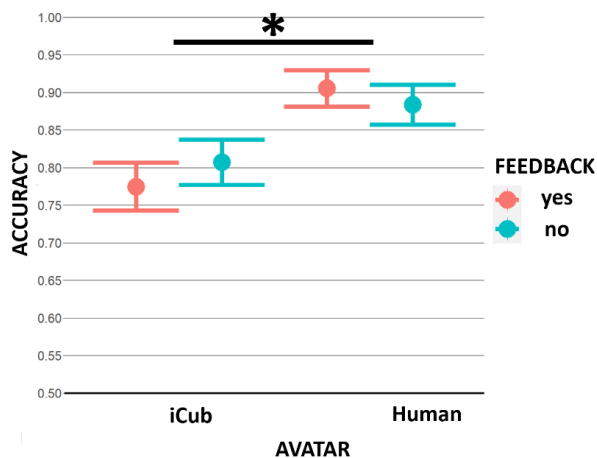


Figure 4. Participants’ accuracy depending on the presence of feedback (red/green) and virtual avatar type (x-axis). On the y-axis, 0.5 represents chance level and 1 represents 100% of accuracy. Asterisk represents a significant difference between the iCub and Human virtual agent conditions (y-axis labels) independent from the presence of feedback.

B. Qualitative Measures

Participants were asked whether they would play the game again in the future. Twenty-three participants answered “yes” (79,3 %), 5 participants could not decide (17,2) and 1 participant replied “no” (3,5%). Participants were also asked which virtual agent they preferred to play with. Thirteen participants picked iCub virtual agent (44,8 %) and 16 participants liked the virtual agents equally (55,2 %).

C. Virtual agent preference effect on RTs and Accuracy

RTs and accuracy were separately submitted to a linear mixed model with type of virtual agent (iCub vs human) and type of preference (iCub vs no preference) as two levels fixed effects. Participants ID was included as a random effect.

Results showed no effect on RTs associated with the participants preference ($\beta_{estimate} = 0.091$, $t(1, 634) = 0.354$, $p = 0.726$).

Results related to accuracy showed a main effect of participants preference ($\beta_{estimate} = 0.209$, $t(1,634) = 3.177$, $p = 0.003$) where accuracy of participants preferring iCub ($M = 0.766$) was significantly lower than the one of participants with no preference ($M = 0.907$). Results also showed a significant interaction ($\beta_{estimate} = 0.145$, $t(1,634) = 3.516$, $p < 0.001$) (see Figure 5). Post hoc comparisons showed that participants who preferred iCub were less accurate when

playing with the iCub virtual agent compared to the other 3 possible conditions (no preference and playing with human virtual agent: $p = 0.007$; no preference and playing with iCub virtual agent: $p = 0.017$; preferring iCub and playing with the human virtual agent: $p > 0.001$).

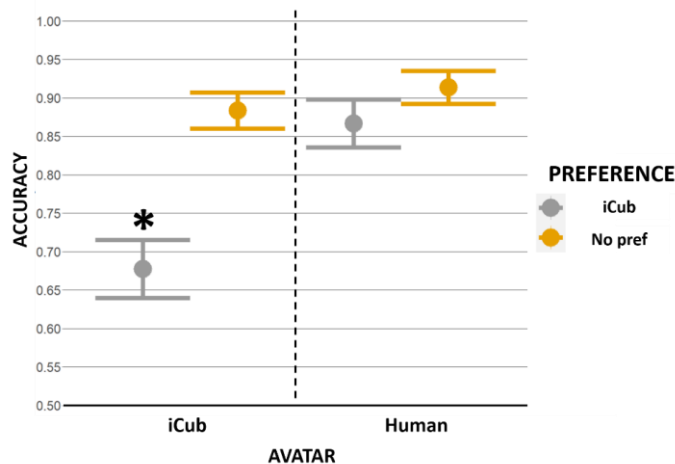


Figure 5. Participants’ accuracy depending on their preference and virtual agent. On the y-axis, 0.5 represents chance level and 1 represents 100% of accuracy. Asterisk describe a condition that is significantly different from all the others.

V. DISCUSSION

The present study aimed to investigate the effects of virtual agent type and social feedback on performance of children diagnosed with ASD in a virtual cups-and-ball game, as well as their subjective preferences towards specific virtual agents. Additionally, the study explored the potential interaction between virtual agent type and feedback

Our results did not provide support for the first hypothesis, which suggested that participants would demonstrate greater accuracy in blocks with feedback compared to blocks without feedback. There was no significant effect of feedback presence on either reaction times (RTs) or accuracy. Contrary to expectations, participants’ performance did not improve when they received feedback from the virtual agents. This finding suggests that the presence of feedback did not serve as a rewarding stimulus influencing participants’ decision-making accuracy in this task. It is possible that the feedback provided by the virtual agents was not influential enough or did not effectively guide participants towards the correct cup choice.

Another possibility is that the feedback provided by seeing the outcome of their chosen cup (whether the ball was actually inside) was more informative for participants than the feedback given by the virtual agents. This direct feedback of the outcome may have been sufficient for participants to perform accurately on the task, rendering the virtual agent feedback less influential or necessary. Interestingly, other studies found abnormal processing of feedback in ASD samples [40, 41]. In order to understand whether social feedback is not potent enough for individual with ASD to

modulate performance in a task, future work would need to address this issue in more detail, for example, by manipulating different types of social feedback and contrasting them with non-social outcomes of the decision.

The second hypothesis proposed that participants would demonstrate higher accuracy when playing with the iCub virtual agent due to the preference for robotic and technological products often observed in individuals with ASD. Contrary to our hypothesis, participants performed better with the human virtual agent than with the iCub virtual agent, as indicated by a significant difference in accuracy across the two conditions. This finding suggests that participants' performance was not positively influenced by the technological appearance of the iCub virtual agent, contrary to initial expectations. This outcome could imply that the preference for technological products might not always translate into improved task performance when interacting with robotics agents.

Interestingly, the accuracy results were not paralleled by reaction time data. The absence of a significant effect on RTs suggests that the preference for iCub primarily impacted the specific moment of the cue and did not have a generalized effect on overall speed of responding. Contrary to typical expectations from cueing task research, we did not observe faster reaction times during correct trials. This might suggest reduced cue attention, but we dismiss this interpretation given the relatively high task accuracy (86%).

Regarding participants' preferences, the majority expressed a willingness to play the game again in the future, with the majority of the participants having no preference towards one agent. However, when examining the effects of virtual agent preference on performance, the results indicated that participants who preferred the iCub virtual agent demonstrated significantly lower accuracy when playing with the iCub virtual agent compared to other conditions. This finding suggests a potential mismatch between participants' preference for the iCub virtual agent and their actual decision-making performance when interacting with that specific virtual agent. It is possible that children who expressed a preference for iCub were more visually engaged or distracted by the robot, leading to decreased accuracy in identifying the correct cup during the task. This interpretation aligns with the finding that there was a decrease in accuracy. The findings also align with the results from the study by Duquette and colleagues [22]. In their study, ASD children interacted either with a robotic or human agent with the goal of imitating actions. Children exposed to robotic agent had reduced behaviors toward other objects and no stereotyped behaviors probably due to interest towards the robot, focusing their attention on the agent rather than on other objects [22]. These results are also in line with other studies finding increased attention directed to the robot compared to other objects (i.e. toys) [11].

It is important to note that individual preferences for specific virtual agents or robots can vary among children with ASD. While some children may find the iCub virtual agent engaging and interesting, others may have different

preferences or responses. These individual differences in preference and attentional focus should be considered when interpreting the results and in future research.

The present study has certain limitations that should be acknowledged. The sample size was relatively small, which may have affected the statistical power to detect small effects. Additionally, the study did not explore the underlying mechanisms driving the observed effects or participants' subjective experiences during the task. Future research could investigate the cognitive and psychological processes underlying the preferences and their impact on decision-making performance. Moreover, exploring different feedback strength/modalities or tailoring feedback to individual participants' preferences may enhance the impact of feedback on decision-making accuracy. In summary, our study aimed to examine the effects of virtual agent type and feedback presence on performance of children diagnosed with ASD in a virtual ball-cup game. Contrary to our first hypothesis, the presence of feedback and the preference for a specific virtual agent type did not significantly impact participants' performance in a decision-making task. This suggests that factors such as social feedback and technological appearance may not be the primary drivers of performance in this context. Instead, individual preferences and attentional factors may play a more significant role in task performance. It is crucial to consider the complexity of the interplay between these factors when designing and implementing virtual interventions for individuals with ASD. Further research is needed to better understand the specific interplay between social feedback and nonsocial outcome (which, in a sense can be considered a type of feedback) in driving task performance of individuals with ASD.

VI. CONCLUSION

In conclusion, our study showed that the preference for iCub among some children may have influenced their attentional focus during the task, potentially leading to decreased accuracy in the task. This finding highlights the importance of considering potential distractions that virtual agents might bring into interventions for children with ASD. Future studies could explore strategies to mitigate distractions or optimize attentional engagement to enhance task performance and overall outcomes.

VII. ETHICAL IMPACT STATEMENT

The study involved 29 children diagnosed with Autism Spectrum Disorder (ASD) recruited from a rehabilitation center, with informed consent obtained from their parents or legal representatives. Adhering to the ethical standards of the Declaration of Helsinki (1964) and approved by the local Ethical Committee, data collection ensured strict confidentiality and participant anonymity through automatically generated ID numbers. To address potential biases, healthcare professionals collecting data remained unaware of the study's hypothesis. However, limitations such as the small sample size and the absence of a control group of neurotypical children were acknowledged, potentially

affecting the statistical power and generalizability of findings. Mitigation strategies were implemented, including transparent reporting to prevent misinterpretation, bias mitigation efforts, and consideration of implications on human rights and individuals' well-being, particularly in the development of virtual interventions for ASD. Acknowledging these limitations, the study emphasizes the need for further research to understand the interplay of factors influencing task performance among individuals with ASD.

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[Removed for anonymization purpose]

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