Comparative Analysis of Perceptions and Interpretations of Autistic Traits in Human and Robotic Agents

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***Abstract*—This research aims to investigate whether individuals interpret autistic traits differently when exhibited by human agents compared to robotic agents. With the increasing integration of artificial intelligence and robotics into daily life, understanding how people perceive and respond to behaviors associated with autism spectrum disorder (ASD) in both human-like and non-human agents is crucial. The study will employ qualitative and quantitative methodologies to explore cognitive, emotional, and behavioral responses to autistic traits in various agent types. Findings from this research will contribute to enhancing our understanding of human-robot interaction dynamics and inform the development of more socially intelligent and empathetic robotic systems.**

***Index Terms*—Human-robot interactions, ASD, human agent, robotic agent**

I. Introduction

Autism Spectrum Disorder (ASD) is a developmental condition characterized by difficulties in social communication and interaction, alongside patterns of restricted or repetitive behaviors and interests [1].

Recent estimates from the CDC's Autism and Developmental Disabilities Monitoring (ADDM) Network suggest that approximately 1 in 36 children are diagnosed with ASD, with some individuals remaining undiagnosed or misdiagnosed until later stages of life [2].

The diagnostic process for autism poses significant challenges due to the absence of a definitive medical test, such as a blood test. Instead, clinicians must rely on their expertise and observational skills to assess and diagnose the condition in children [8].

Autism spectrum disorder (ASD) encompasses a broad spectrum of behaviors, often presenting a challenge for non-specialists in recognizing its symptoms due to its diverse and nuanced nature. For instance, a clinician might overlook potential signs of ASD because the observed behaviors, such as occasional eye contact or smiling, seem incongruent with their perception of the disorder. However, it's crucial to understand that the essence of autism lies not merely in the presence or absence of these behaviors but rather in how they manifest in social interactions. Furthermore, assessments conducted by clinicians often capture only a snapshot of an individual's behavior, potentially missing crucial insights into their condition that parents may observe at home or in other social environments. Thus, a comprehensive understanding of ASD necessitates recognizing its multifaceted nature and acknowledging the importance of longitudinal observations in different contexts. [3]

To address these issues a lot of researches were conducted by specialists from different fields and while there are improvements in the diagnosing process there is still a huge lack of reliable and accessible tools that would be able to distinguish behavioral patterns of normally developing children from autistic spectrum disorder symptoms. The symptoms of autism spectrum disorder can vary significantly from one child to another, often making it challenging to differentiate them from typical behaviors or symptoms of other disorders, such as ADHD.

Numerous projects have been developed to facilitate interaction with children, employing robots as diagnostic and teaching tools, resulting in valuable improvements in children's behaviors. [5]–[7] However, it's crucial to note that a significant number of symptoms, particularly those associated with mild and moderate autism spectrum disorder, often go undetected by humans, leading to a lack of appropriate treatment for affected children. In contrast, robotic behaviors are programmed and thus perceived differently by people. Their actions are predetermined and repeatable which may help people to learn and distinguish them in human behavior.

Therefore, this research aims to conduct a comparative analysis of the perceptions and interpretations of autistic traits of children in human and robotic agents. By examining how humans perceive and respond to these traits in different agents, the study seeks to contribute valuable insights to the field of HRI. These findings hold the potential to enhance assessment methods for children with autism spectrum disorder and facilitate clinicians and other specialists in recognizing a broader spectrum of symptoms, particularly those associated with moderate severity and severe forms of ASD. Ultimately, this research endeavors to improve diagnostic accuracy and provide more effective interventions for individuals with ASD.

II. Background and Related Work

During the past decade, Social Robotics has gained more use in the therapeutic field, particularly in pediatrics. And particularly Autism Spectrum Disorder (ASD) started to draw more and more attention from the specialists of HRI. [2]

Many of their projects, like the works of K. Dautenhahn [6], or the initiative AskNAO [7] have proved that robots are effective in ASD diagnosing and assessment. [4] According to them, robots can establish a stable and consistent environment while facilitating social interactions during structured activities. Moreover, their capacity to execute tasks or activities with unwavering uniformity is invaluable for discerning and analyzing behavioral patterns across various children within identical environments and circumstances. This attribute holds particular significance in the context of working with individuals diagnosed with autism spectrum disorder.

There are not many works in the proposed area of research, but the research field in robotic personality and human likeness encounters a significant amount of related works.

In the study M. Y. Lim et. al. [10] with a Robo-Barista it is shown that it is possible to accurately portray personality in a social robot, in terms of extroversion-introversion using vocal cues and linguistic features. Secondly, it was established that for the context of the study, an extrovert robot is preferred and trusted more than an introvert robot, regardless of the subject's own personality.

In another work, which was conducted by Anna-Maria Velentza et. al., different robot personalities and human preferences of them were studied. In the study, the robot's modalities were manipulated on its body movements (expressive arm and head gestures) while performing the storytelling, friendly attitude expressions and storytelling, and personality traits. After the robot's storytelling, participants filled out a knowledge acquisition questionnaire and a self-reported enjoyment level questionnaire. In the second part, there is the idea of participants witnessing a conversation between the robots with the different modalities, and they were asked to choose the robot with which they want to collaborate in a similar activity. The findings were that participants prefer to collaborate with robots with a cheerful personality and expressive body movements. Especially when they were asked to choose between two robots that were cheerful and had expressive body movements, they preferred the one that originally told them the story. Moreover, participants did not prefer to collaborate with a robot with an extremely friendly attitude and storytelling style. [11]

Wykowska, A. et. al. in their study [9] examined individual differences in sensitivity to human-like features of a robot's behavior. They performed a non-verbal Turing test with a humanoid robot, where participants judged whether the robot's behavior was programmed or human-controlled. The study proves that people with more autistic traits are less sensitive to the difference between the conditions. However, it is not stated which of the behaviors of the robot was preferable.

According to the discussed studies, people can perceive the difference between a human-operated robot and a fully autonomous robot. The accuracy of the perception depends mostly on the subject's personality traits, and people with more autistic traits are less sensitive to this difference. Additionally, a robot's likability depends on its personality traits, in most cases, the robot extrovert was more trustworthy and pleasant to the participants than the one with introvert traits. Additionally, participants expressed some tendency toward anthropomorphism towards the robots. People would prefer the robot they interacted with over a newly presented one.

The robots presented in those studies had a certain function and were designed to act accordingly. However, it remains uncertain whether people will react differently to robots that mimic certain real social behavioral traits, such as autistic traits, particularly in simulated casual situations.

But firstly, there is a question of whether it is possible to implement autistic traits into a robot and if this behavior will look natural and understandable for humans. This aspect was studied in Kim Baraka and Francisco S. Melo work [12]. Researchers explore a novel approach to utilizing robots in relation to Autism Spectrum Disorder by programming a humanoid robot to exhibit behaviors similar to those observed in children with ASD. They developed 16 'autism-like' behaviors with varying severity levels on a NAO robot, based on ADOS-2, the gold standard for ASD diagnosis. These behaviors cover verbal and non-verbal dimensions and represent a spectrum of typical ASD responses to three different stimulus families inspired by standard diagnostic tasks. These behaviors were integrated into an autonomous agent running on the robot, allowing humans to continuously interact with it through predefined stimuli. The validity of the interactive robot was evaluated through both video-based and 'in situ' studies involving three therapists. Additionally, subjective evaluations were presented regarding the potential benefits of such robots, including complementing existing therapist training and enabling novel tasks for ASD therapy.

The study proves that autistic traits are possible to incorporate in a robot. They are valid and possible to perceive. However, it is important to analyze the difference between real human behaviors and a robot's programmed traits, and if this difference influences people's perception.

III. Research Questions

As was discussed earlier, it is possible to use robots with autism-like behavior for teaching and training purposes. However, it is still unexplored what aspects of autism-like behavior are represented differently in robots and humans. To address this uncertainty, this research will focus on the difference in perception of real human autistic traits and programmed autism-like traits in a robot.

Based on the results in [12], to correctly incorporate autism-like behavior into a robot Autism Diagnostic Observation Schedule 2 (ADOS-2) model will be used. The key aspects of this model will be discussed later in the Implementation section. The autism-like behaviors will include both verbal and non-verbal dimensions of autism behavior as it allows for creating a wider range of situations. The same type of behavior will be incorporated into a human model. To investigate the difference in perception of robotic and human autism-like behaviors the interactive situation with a human and a robot will be simulated.

In this research, the behavioral difference will be investigated in two different situations, such as 'Calling for joint attention' and 'Calling by name'. The identical scenarios will also be employed for the human agent, with comprehensive descriptions provided in the Robotic Implementation section of this paper.

To provide a comparison of the same behavior in different situations and different agents the following question will be used:

1) Do people interpret differently the same behavior in a human agent and a robotic agent?

To answer this question videos of the 'Calling for joint attention' and 'Asking for snack preference' scenarios with a robot and a human agent will be filmed. Those videos will be shown to the participants with a post-questionnaire. The questionnaire will ask questions about the perception of the agents' behavior. The data analysis will attempt to find the difference between the participants perceptions of the same behavior in different agents.

For each scenario, the stimuli of different families will be used to get a wide range of behaviors. Thus, a significant difference between scenarios will appear. To address this issue the following question will be answered:

2) Does the difference between scenarios influence peoples' perception of the agent?

To answer this question the videos with different scenarios of an agent will be shown to participants. After each video, a survey will be conducted. In the survey, the participants will be asked to rate their perception of the agent. The data will be analyzed to determine whether the difference in perception of different scenarios of the same agent occurs.

IV. ROBOTIC IMPLEMENTATION

In this section, we will describe different models and software that were used to program different robot-agent behaviors, as well as corresponding human-agent behaviors. The different autistic-like behaviors were programmed based on the study [12] and the ADOS-2 model.

A. Behavioral Design by ADOS-2 model

Autism Diagnostic Observation Schedule 2 (ADOS-2) model stands as an advanced diagnostic tool, employing interactive engagement and careful observation to assess a child's behaviors within a controlled setting. Therapists guide the child through a structured series of 10 tasks, employing standardized materials and procedures. Subsequently, they meticulously record the observed behaviors, encapsulating them into discrete values across various behavioral dimensions. Typically, an ADOS-2 session spans 40 to 60 minutes, adapting to the child's age and language proficiency through available modules. [13] The design of different behaviors will center around Module 2, tailored for children with phrase speech abilities. This will offer a more extensive repertoire of behaviors for analysis. Table I illustrates a sample ADOS-2 featured behavior and relevant task steps for each feature level.

Inclusion of autism-like behavior was limited to moderate (1) and high (2) severity levels, with an additional idle (0) severity level for comparative analysis. This decision was made due to the nuanced distinction between these levels and typical behavioral patterns in humans.

In this research, based on the ADOS-2 model tasks and insights from [12], the focus was on categorizing two primary features: 'Name Call' and 'Joint Attention Response'. For each feature, three distinct states were defined to correspond with the initial three levels of autism severity. For example, the stimuli for the 'Name Call' feature included 'calling the robot's name up to 4 times' and 'touching the robot to attract attention'. The responses to these stimuli were as follows:

- Response on the first/second attempt, direct eye-contact, accompanied by the following speech 'Yes?'
- Postponed response to the verbal stimulus, with the robot looking in the general direction of the sound
- No reaction to the verbal stimuli, with slight eye movement towards the calling person after a touch.

These stimuli and responses were adapted from the materials presented in [12], upon which Table 2 was constructed.

The robot demonstrated all behaviors autonomously, with responses diligently hardcoded to ensure appropriateness across varying severity levels. To mimic eye movements, the color of the eye LEDs was programmed to change in response to stimuli received by the robot and the severity level of the scenario.

TABLE I
FEATURE CODING AND HIERARCHY OF PRESSES

Feature 'Response to Joint Attention'	Task 'Call attention towards an object':Hierarchy of presses
0 = Immediate reaction to verbal stimuli; direct eye-gaze.	(1) Call the agent's attention with general attention stimulus - 'Look!', repeat up to 4 times
1 = Postponed reaction to verbal stimuli; no eye-contact;eye-gaze in the direction of the object.	(2) Call the agent's attention with a direct stimulus: 'Look at THAT!'.
2 = No reaction to verbal stimuli; no eye-contact; eye-gaze in the direction of the object.	(3) Make an object to produce noise or/and light stimuli
3 = No reaction to verbal stimuli; no eye-contact; no eye-gaze in the direction of the object	(4) Touch the child to catch his/her attention and point on the object

[a] A simplified example of severity levels of a feature (left) with task steps relevant for the expressed behaviors (right). (The table adapted from [12])

TABLE II
TASK PROTOCOL TABLE

Stimulus Family	Relevant Feature	Severity 0	Severity 1	Severity 2
Calling Name	Response to Name	Response on the first/second attempt, direct eye-contact, accompanied by the following speech 'Yes?'	Postponed response to the verbal stimulus, with the robot looking in the general direction of the sound	No reaction to the verbal stimuli, with slight eye movement towards the calling person after a touch.
Calling for Joint Attention	Response to Joint Attention	Immediate reaction on the stimulus: agent looks at object then back at human then back at object	Reaction postponed, only on the direct stimulus 'THAT'. Agent looks in area of the object	No reaction to verbal stimuli. Agent only looks at object when activated and emitting sound

In the scenario with a severity level of 0, the eye LEDs transitioned from white to bright yellow to accurately indicate the robot's focus on the interaction. Additionally, eye blinking was incorporated to imbue the robot with a lifelike and dynamic expression. For scenarios two and three, the eye LEDs shifted from white to light yellow to simulate a dissociated attention, consistent with individuals with ASD.

Object recognition was programmed with stringent positional parameters due to the robot's limitations in understanding its environment. Movements of the robot were meticulously crafted using the software's animation feature 'timeline' (refer to subsection 'Software') to ensure natural behavior that aligned with the context of the experiments.

B. Hardware description: Nao-Robot from SoftBank Robotics

For this research, we employed a physical Nao-Robot (V6) manufactured by SoftBank Robotics (formerly Aldebaran Robotics), provided by RoboHub, University of Waterloo [15]. It includes directional microphones, dual cameras, text-to-speech, built-in natural language processing and image recognition, and a global user base [15]. The appearance of the robot and its general characteristics are depicted in Figure 1. This choice was based on several factors, including its

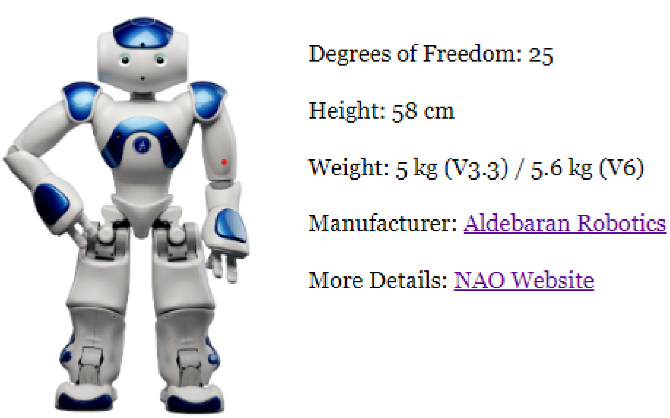


Fig. 1. Robot Nao and its general characteristics

mechanical superiority compared to other robots, straightforward programming capabilities, and the ability to develop precise social behaviors akin to those observed in humans. Moreover, this particular robot model was utilized in a prior study [12], which employed similar behaviors and coding methodologies. For representing the behaviors listed in Table 2, we utilized the following hardware components: a speech recognition module, sound recognition system, eye LEDs, neck joint, touch sensor on the robot's head, and a speech generator. In Scenario 1 (0 severity level) as detailed in Table 1, all hardware components were utilized except for the touch sensor. In Scenario 2 (1 severity level), only the eye LEDs, neck joint, and speech recognition module were activated. Lastly, in Scenario 3 (2 severity level), the touch sensor, neck joint, and sound recognition system were utilized.

C. Software Description: Choreographe Software from SoftBank Robotics

The 'Choreographe' software, developed specifically by the manufacturers for programming the Nao Robot, was employed for our programming tasks. This application facilitates the creation of animations and behaviors, allowing users to test them on simulated or real robots while monitoring and controlling the NAO. It offers programming capabilities through both a no-code interface and Python scripting. [16] Figure 2 illustrates the coding process.

In our research, we utilized both approaches - the no-code interface and Python scripts - to program the behaviors listed in Table II. The created code can be found in Appendix A.

V. METHODOLOGY

To gather relevant results and address the mentioned research questions, we opted for a mixed factorial design as the experimental approach. The rationale behind this choice will be expounded upon in the following subsections.

A. Overall design

To address the research questions outlined in the relevant section, we employed two agents: a human and a robot, to enact three scenarios as described in Table II. To ensure the accurate representation of behaviors and to address ethical concerns, the researcher was selected to act as a human agent. Scenarios involving the human agent replicated those with the robot agent, responding identically for consistency. The primary difference in the simulations lay in the agents themselves.

The research was conducted in two separate plain rooms, each furnished with a table. This arrangement ensured a

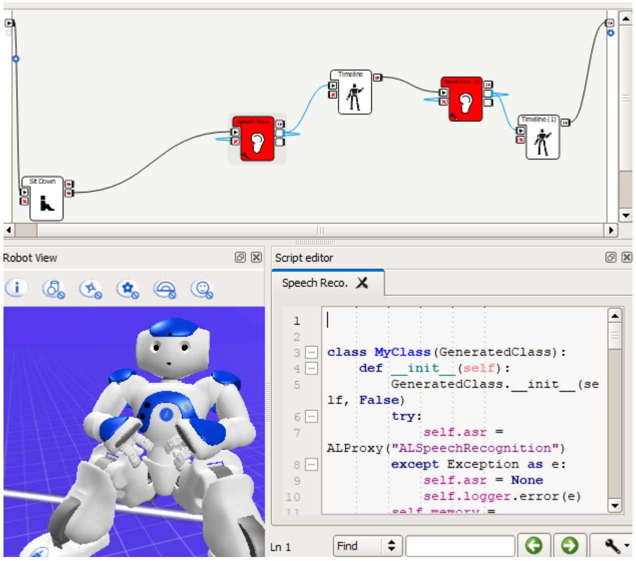


Fig. 2. Programming Nao Robot in Choreographe

distinct contextual difference between the rooms, which was crucial for investigating the second research question.

As detailed in the 'Behavioral Design' subsection of the 'Robotic Implementation' section, all three scenarios featured an object for the agents to focus on. To fulfill this requirement, a mobile phone was selected due to its ubiquity in everyday life and its ability to emit sound and vibrations, which were essential for the third scenario with a severity level of 2. No other objects were introduced into the environment to maintain the focus on the task context.

In scenarios with severity levels 0 and 1, the person interacting with the agent remained positioned directly in front of the agent throughout the experiment. However, in the third scenario, the person moved closer to the side of the agent to administer a 'Touch' stimulus, as specified in the scenario description.

B. Participants

For the user research, we recruited a total of 11 participants, divided into two groups: one consisting of 6 individuals and the other of 5. The participants were allocated randomly to these groups, ensuring that one group did not have close familiarity with the human agent, thereby enhancing the relevance and objectivity of the results.

To engage potential participants, email invitations and links were widely circulated among network of the researcher as well as among the classmates. There were no prerequisites for inclusion. The participants comprised 4 females and 7 males, spanning an age range from 21 to 50 years old. With diverse backgrounds, they brought a wealth of perspectives and experiences to the study, enhancing the depth and breadth of insights gathered.

C. Procedures and measures

To effectively address our research inquiries, we will employ a blend of qualitative and quantitative research methodologies, recognizing that this combination offers a comprehensive understanding of the phenomenon under investigation. Participants will be presented with a survey focusing on the dependent variables, allowing for detailed insights into their experiences.

Given our two independent variables and the incorporation of three distinct levels for observing social interaction, our study will adopt a 3-by-3 factorial design. This design enables us to systematically manipulate and examine the effects of these variables, facilitating a nuanced analysis of their interplay and impact on the outcomes of interest.

Data collection from participants was conducted through an online survey. Two separate surveys were developed for the two participant groups, each sharing a common structure.

The initial section of both surveys comprised demographic inquiries, aimed at gathering essential background information. Subsequently, the second section aimed to gauge participants' general level of emotional intelligence.

The third section presented participants with three videos depicting behaviors characterized by varying levels of ASD severity. To mitigate bias, the videos were randomly arranged. Following each video, participants responded to questions probing their perceptions of the exhibited behavior.

To address the first research question, participants were tasked with rating the behavior depicted in each video based on clarity, severity level, and perceived difference observed in each scenario.

To explore the second research question, participants were prompted to provide feedback on their levels of empathy and understanding towards the agent featured in the videos.

Additionally, a subsection featuring questions regarding general awareness of ASD was included in the survey.

For the survey involving scenarios with the robot agent, an additional section was incorporated to inquire about participants' general experience with robots.

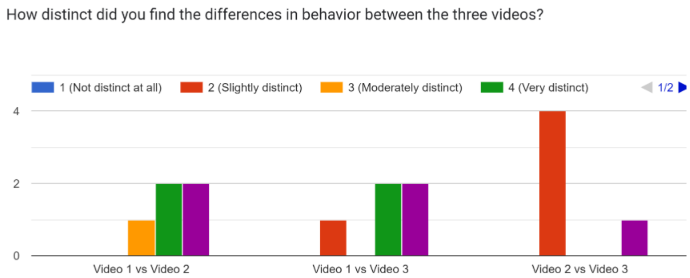
VI. Results

Despite the modest sample size, significant distinctions emerged between the two groups studied. To enhance interpretation and reduce bias, we've decoded the video names from the questionnaire into two categories: Human 1-3 and Robot 1-3.

To facilitate the comprehension of visual representations such as diagrams, we will employ the respective designations 'Human Diagram' and 'Robot Diagram'. Additionally, to enhance the interpretation of the results, the severity level of each video has been decoded and is presented in Table III. For the first research question, significant results are evident from Figures 3 and 4, illustrating participants' perceptions of the

TABLE III
DECODING OF VIDEOS FROM USER SURVEY BY ASD SEVERITY LEVEL

	Video 1	Video 2	Video 3
Human	0 Severity Level	2 Severity Level	1 Severity Level
Robot	1 Severity Level	0 Severity Level	2 Severity Level



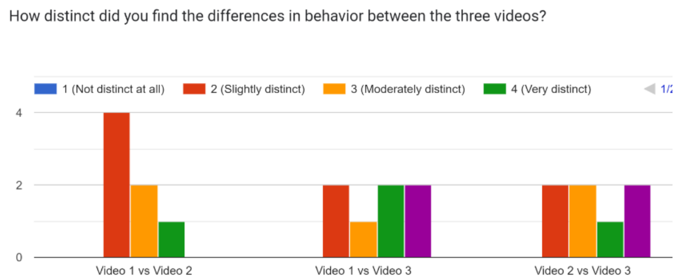
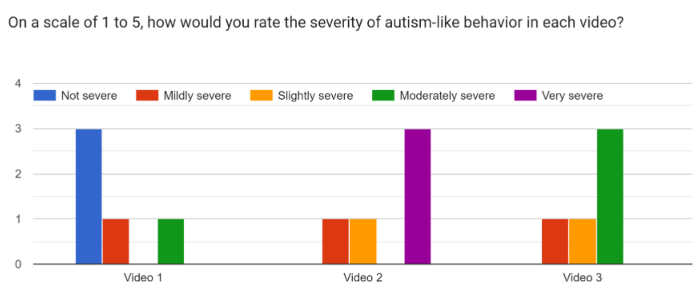


Fig. 3. and Fig. 4. Human Diagram (upper) and Robot Diagram (lower): How distinct the behaviors represented in each video are.

differences between each pair of videos. Notably, participants perceived a more distinct difference between severity levels 1 and 2 in the robot agent videos compared to the human agent videos. Additionally, while most participants acknowledged the difference between severity levels 0 and 1, responses for this comparison were polarized on opposite ends of the scale for the human agent videos, whereas all responses aligned with one size of the scale for the robot agent videos.

Another significant finding is depicted in Figures 5 and 6, where participants rated the level of ASD severity for the agents in each video.



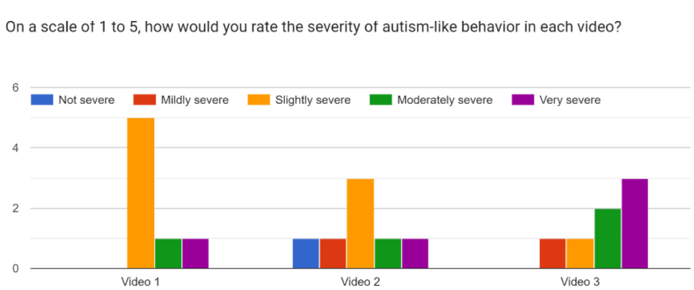
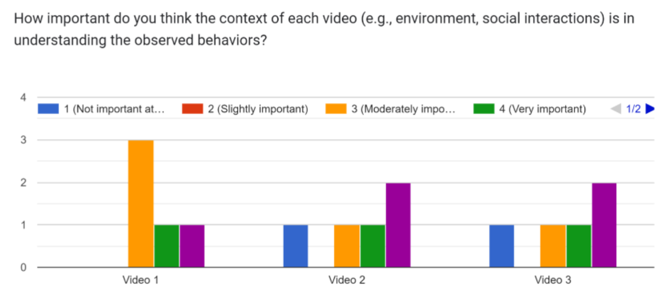


Fig. 5. and Fig. 6. Human Diagram (upper) and Robot Diagram (lower): Rate the level of ASD severity in each video.

In contrast, for Robot 1-3, participants' responses were less polarized, but they consistently chose the correct side of the severity scale for each case. However, participants encountered some difficulty in rating the normal behavior of the robot.

Regarding the second research question, valuable insights were gleaned from questions about the context of each interaction. Figures 7 and 8 illustrate that for videos featuring a human agent exhibiting 1 and 2 severity levels of ASD, the context was deemed significantly more important than for the robot agent displaying similar behaviors.

Overall findings indicate that the robot agent elicited less empathy than the human agent. Additionally, the open feedback section in the survey featuring the human agent revealed that while participants' quantitative perceptions of the behaviors were accurate, qualitatively, the behaviors were not perceived as distinctly autistic but rather indicative of an anxious state in the agent.



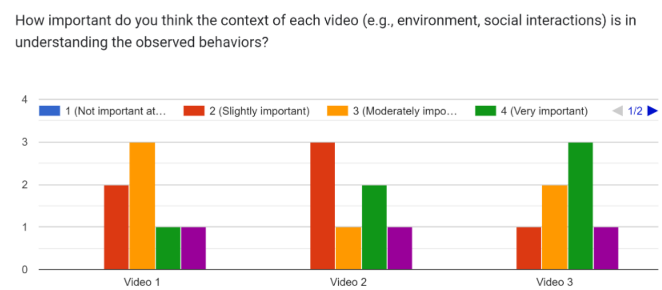


Fig. 7. and Fig. 8. Human Diagram (upper) and Robot Diagram (lower): The importance of the context of each video.

VII. Discussion

The findings of the study shed light on several noteworthy distinctions between participants' perceptions of videos featuring human and robot agents, particularly regarding the severity of Autism Spectrum Disorder (ASD) traits and the importance of context in evaluating interactions.

Firstly, participants demonstrated a more consistent perception of severity levels in videos featuring robot agents compared to those with human agents. While responses for the human agent videos showed polarization, participants generally aligned their assessments for the robot agent videos, indicating a clearer understanding of ASD severity in robotic interactions. This suggests that participants may find it easier to objectively evaluate robotic behavior compared to human behavior, possibly due to reduced emotional bias or preconceived notions.

Interestingly, participants placed greater emphasis on contextual factors in evaluating interactions involving human agents with ASD traits compared to those involving robot agents. This implies that participants perceive human behavior within a broader social context, whereas they may attribute ASD traits to robotic behavior more independently of contextual cues. This finding underscores the complexity of human-robot interactions and highlights the need for further research into how contextual factors influence perceptions of robotic behavior.

Furthermore, the study reveals a discrepancy in empathetic responses towards human and robot agents, with participants demonstrating less empathy towards the robot agent. This disparity may stem from participants' tendency to view human-agents as more relatable and deserving of empathy compared to robot agents, which are perceived as less sentient and emotionally responsive.

The qualitative analysis of open feedback further elucidates participants' perceptions, indicating that while participants accurately identified ASD behaviors in human agents, they interpreted these behaviors as indicative of anxiety rather than autism. This finding suggests a potential limitation in the ability of participants to accurately discern ASD traits in human behavior, showcasing the importance of refining robotic simulations to better mimic human ASD behaviors.

Based on these conclusions we can answer our research questions.

1) Do people interpret differently the same behavior in a human agent and a robotic agent?

Yes, people interpret the same behavior differently in a human agent compared to a robotic agent. The study's findings indicate that participants demonstrated a more consistent perception of severity levels in videos featuring robot agents compared to those featuring human agents. Additionally, participants placed greater emphasis on contextual factors in evaluating interactions involving human agents with Autism Spectrum Disorder (ASD) traits compared to those involving robot agents. This suggests that individuals may attribute human-like behaviors, such as ASD traits, differently depending on whether they are observed in a human or a robotic agent.

2) Does the difference between scenarios influence peoples' perception of the agent?

Yes, the difference between scenarios does influence people's perception of the agent. The study found that participants placed greater importance on contextual factors in evaluating interactions involving human agents with ASD traits compared to those involving robot agents. This suggests that individuals perceive human behavior within a broader social context, whereas they may attribute ASD traits to robotic behavior more independently of contextual cues. This indicates that the scenario or context of an interaction can significantly impact how individuals perceive and interpret the behavior of agents, whether human or robotic.

While the findings have undoubtedly provided valuable insights into addressing the research questions, it's imperative to recognize and address several significant limitations that require careful consideration. These include the relatively modest sample size, discrepancies in group balance, and the absence of validation from medical specialists for the behaviors exhibited by the agents. Additionally, ethical considerations such as the incorporation of autistic behaviors into robots and the portrayal of videos depicting human and robotic agents performing such behaviors should be thoroughly deliberated upon. These ethical implications demand thoughtful reflection and adherence to ethical guidelines to ensure the responsible and respectful treatment of individuals with autism spectrum disorder (ASD) in research endeavors.

VIII. Conclusion

The study's findings illuminate key distinctions in participants' perceptions of videos featuring human and robot agents, particularly regarding Autism Spectrum Disorder (ASD) traits and the influence of context on interactions. Participants showed more consistent assessments of ASD severity in robot agent videos, indicating a potential for reduced emotional bias compared to human agent videos. Moreover, they emphasized contextual factors more in evaluating human agent interactions, suggesting a nuanced understanding of human behavior within social contexts. Additionally, participants displayed less empathy towards robot agents, possibly due to perceived differences in sentience. Qualitative feedback revealed challenges in accurately identifying ASD traits in human behavior, highlighting the importance of refining robotic simulations.

However, significant limitations such as sample size, group imbalances, and the lack of validation from medical specialists must be addressed. Additionally, ethical considerations surrounding the portrayal of ASD behaviors in robots and videos warrant careful deliberation to ensure respectful and responsible research practices.

IX. Future Work

The findings of this research hold promise for the advancement of clinical teaching methods and offer novel approaches for preparing specialists to work effectively with children diagnosed with Autism Spectrum Disorder (ASD). Furthermore, these insights could inform the development of innovative visualization tools aimed at improving the training of individuals who regularly interact with children but lack medical expertise.

In future research endeavors, a more extensive user testing process should be conducted, supplemented by broader sample testing to ensure the generalizability of the results. Prior to initiating user research, it is imperative to validate the behaviors exhibited by both human and robot agents with ASD traits through consultation with medical professionals. Additionally, exploring ethical considerations related to the use of such technologies in educational settings would be a valuable avenue for further investigation.

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Appendix

Program Code: Robot Behaviors

A. Eye LEDs

```
class MyClass(GeneratedClass):
   def __init__(self):
      GeneratedClass.__init__(self, False)

   def onLoad(self):
      self.fadeOps = []
      self.leds = self.session().service("ALLeds")

   def onUnload(self):
      #~ puts code for box cleanup here
      pass

   def onInput_color(self, p):
      if( self.getParameter("Side") == "Left" ):
         sGroup = "LeftFaceLeds"
      elif( self.getParameter("Side") == "Right" ):
         sGroup = "RightFaceLeds"
      else:
         sGroup = "FaceLeds"
      fadeOp = self.leds.fadeRGB(sGroup, 256*256*p[0] + 256*p[1] + p[2],
      self.getParameter("Duration (s)"), _async=True)
      self.fadeOps.append(fadeOp)
      fadeOp.wait()
      self.fadeOps.remove(fadeOp)
      if( self.fadeOps == [] ):
         self.onDone() # activate output of the box
```

B. Speech Recognition

```

class MyClass(GeneratedClass):
   def __init__(self):
      GeneratedClass.__init__(self, False)
      try:
         self.asr = ALProxy("ALSpeechRecognition")
      except Exception as e:
         self.asr = None
         self.logger.error(e)
      self.memory = ALProxy("ALMemory")

   def onLoad(self):
      from threading import Lock
      self.bIsRunning = False
      self.mutex = Lock()
      self.hasPushed = False
      self.hasSubscribed = False
      self.BIND_PYTHON(self.getName(), "onWordRecognized")

   def onUnload(self):
      from threading import Lock
      self.mutex.acquire()
```

```
        try:
            if (self.bIsRunning):
                if (self.hasSubscribed):
                    self.memory.unsubscribeToEvent("WordRecognized", self.getName())
                if (self.hasPushed and self.asr):
                    self.asr.popContexts()
        except RuntimeError, e:
            self.mutex.release()
            raise e
        self.bIsRunning = False;
        self.mutex.release()

    def onInput_onStart(self):
        from threading import Lock
        self.mutex.acquire()
        if(self.bIsRunning):
            self.mutex.release()
            return
        self.bIsRunning = True
        try:
            if self.asr:
                self.asr.setVisualExpression(self.getParameter("Visual expression"))
                self.asr.pushContexts()
            self.hasPushed = True
            if self.asr:
                self.asr.setVocabulary( self.getParameter("Word list").split(';'),
                self.getParameter("Enable word spotting") )
            self.memory.subscribeToEvent("WordRecognized",
            self.getName(), "onWordRecognized")
            self.hasSubscribed = True
        except RuntimeError, e:
            self.mutex.release()
            self.onUnload()
            raise e
        self.mutex.release()

    def onInput_onStop(self):
        if( self.bIsRunning ):
            self.onUnload()
            self.onStopped()

    def onWordRecognized(self, key, value, message):
        if(len(value) > 1 and value[1] >=
        self.getParameter("Confidence threshold (%)")/100.):
            self.wordRecognized(value[0]) #~ activate output of the box
        else:
            self.onNothing()
```

C. Eye Blink

```
import time

class MyClass(GeneratedClass):
    def __init__(self):
        GeneratedClass.__init__(self, False)
```

```
    def onLoad(self):
        self.leds = self.session().service("ALLeds")

    def onUnload(self):
        #~ puts code for box cleanup here
        pass

    def onInput_onStart(self):
        rDuration = 0.05
       #------------------------code adjusted myself------------------------
    def onInput_onStart(self):
        rDuration = 0.05
        self.leds.fadeRGB( "FaceLed0", 0x000000, rDuration, _async=True )
        self.leds.fadeRGB( "FaceLed1", 0x000000, rDuration, _async=True )
        self.leds.fadeRGB( "FaceLed2", 0xffa500, rDuration, _async=True )
        self.leds.fadeRGB( "FaceLed3", 0x000000, rDuration, _async=True )
        self.leds.fadeRGB( "FaceLed4", 0x000000, rDuration, _async=True )
        self.leds.fadeRGB( "FaceLed5", 0x000000, rDuration, _async=True )
        self.leds.fadeRGB( "FaceLed6", 0xffa500, rDuration, _async=True )
        self.leds.fadeRGB( "FaceLed7", 0x000000, rDuration, _async=True )
-------------------------------------------------------------------------------
        time.sleep( 0.1 )
        self.leds.fadeRGB( "FaceLeds", 0xffa500, rDuration )
        self.onDone()
```

D. Timeline Movements *Designed myself, code is auto generated*

```
                <Box name="Timeline (1)" id="6" localization="8" tooltip="This box is
                   ↪  empty (contains a single motion layer with no motor position&#
                   ↪ x0A;defined in it) and should be used to create any animation
                   ↪ you would like." x="1080" y="209">
          <bitmap>media/images/box/movement/move.png</bitmap>
          <script language="4">
            <content>
              <![CDATA[]]>
            </content>
          </script>
          <Input name="onLoad" type="1" type_size="1" nature="0" inner="1" tooltip="
             ↪ Signal sent when diagram is loaded." id="1" />
          <Input name="onStart" type="1" type_size="1" nature="2" inner="0" tooltip="
             ↪ Box behavior starts when a signal is received on this input." id="2"
             ↪ />
          <Input name="onStop" type="1" type_size="1" nature="3" inner="0" tooltip="
             ↪ Box behavior stops when a signal is received on this input." id="3"
             ↪ />
          <Output name="onStopped" type="1" type_size="1" nature="1" inner="0"
             ↪ tooltip="Signal sent when box behavior is finished." id="4" />
          <Timeline enable="1" fps="25" start_frame="1" end_frame="-1" size="50">
            <BehaviorLayer name="Look_At_Object">
              <BehaviorKeyframe name="keyframe1" index="1">
                <Diagram>
                  <Box name="Blink" id="1" localization="8" tooltip="This box makes the
                     ↪  robot blink once." x="357" y="262">
                    <bitmap>media/images/box/interaction/LED.png</bitmap>
                    <script language="4">
                      <content>
```

```
                    <![CDATA[import time

class MyClass(GeneratedClass):
   def __init__(self):
      GeneratedClass.__init__(self, False)

   def onLoad(self):
      self.leds = self.session().service("ALLeds")

   def onUnload(self):
      #~ puts code for box cleanup here
      pass

   def onInput_onStart(self):
      rDuration = 0.05
      self.leds.fadeRGB( "FaceLed0", 0x000000, rDuration, _async=True )
      self.leds.fadeRGB( "FaceLed1", 0x000000, rDuration, _async=True )
      self.leds.fadeRGB( "FaceLed2", 0xffa500, rDuration, _async=True )
      self.leds.fadeRGB( "FaceLed3", 0x000000, rDuration, _async=True )
      self.leds.fadeRGB( "FaceLed4", 0x000000, rDuration, _async=True )
      self.leds.fadeRGB( "FaceLed5", 0x000000, rDuration, _async=True )
      self.leds.fadeRGB( "FaceLed6", 0xffa500, rDuration, _async=True )
      self.leds.fadeRGB( "FaceLed7", 0x000000, rDuration, _async=True )
      time.sleep( 0.1 )
      self.leds.fadeRGB( "FaceLeds", 0xffa500, rDuration )
      self.onDone()]]>
                  </content>
                </script>
                <Input name="onLoad" type="1" type_size="1" nature="0" inner="1"
                   ↪ tooltip="Signal sent when diagram is loaded." id="1" />
                <Input name="onStart" type="1" type_size="1" nature="2" inner="0"
                   ↪ tooltip="Box behavior starts when a signal is received on this
                   ↪  input." id="2" />
                <Output name="onDone" type="1" type_size="1" nature="1" inner="0"
                   ↪ tooltip="Signal sent when box behavior is finished." id="3" />
              </Box>
              <Box name="Blink (1)" id="2" localization="8" tooltip="This box makes
                 ↪  the robot blink once." x="594" y="250">
                <bitmap>media/images/box/interaction/LED.png</bitmap>
                <script language="4">
                  <content>
                    <![CDATA[import time

class MyClass(GeneratedClass):
   def __init__(self):
      GeneratedClass.__init__(self, False)

   def onLoad(self):
      self.leds = self.session().service("ALLeds")

   def onUnload(self):
      #~ puts code for box cleanup here
      pass

   def onInput_onStart(self):
      rDuration = 0.05
```

```
    self.leds.fadeRGB( "FaceLed0", 0x000000, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed1", 0x000000, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed2", 0xffa500, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed3", 0x000000, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed4", 0x000000, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed5", 0x000000, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed6", 0xffa500, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed7", 0x000000, rDuration, _async=True )
    time.sleep( 0.1 )
    self.leds.fadeRGB( "FaceLeds", 0xffa500, rDuration )
    self.onDone()]]>
                     </content>
                    </script>
                    <Input name="onLoad" type="1" type_size="1" nature="0" inner="1" tooltip="Signal sent when diagram is loaded." id="1" />
                    <Input name="onStart" type="1" type_size="1" nature="2" inner="0" tooltip="Box behavior starts when a signal is received on this input." id="2" />
                    <Output name="onDone" type="1" type_size="1" nature="1" inner="0" tooltip="Signal sent when box behavior is finished." id="3" />
                  </Box>
                  <Box name="Blink (2)" id="3" localization="8" tooltip="This box makes the robot blink once." x="798" y="285">
                    <bitmap>media/images/box/interaction/LED.png</bitmap>
                    <script language="4">
                     <content>
                      <![CDATA[import time

class MyClass(GeneratedClass):
  def __init__(self):
    GeneratedClass.__init__(self, False)

  def onLoad(self):
    self.leds = self.session().service("ALLeds")

  def onUnload(self):
    #~ puts code for box cleanup here
    pass

  def onInput_onStart(self):
    rDuration = 0.05
    self.leds.fadeRGB( "FaceLed0", 0x000000, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed1", 0x000000, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed2", 0xffa500, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed3", 0x000000, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed4", 0x000000, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed5", 0x000000, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed6", 0xffa500, rDuration, _async=True )
    self.leds.fadeRGB( "FaceLed7", 0x000000, rDuration, _async=True )
    time.sleep( 0.1 )
    self.leds.fadeRGB( "FaceLeds", 0xffa500, rDuration )
    self.onDone()]]>
                     </content>
                    </script>
                    <Input name="onLoad" type="1" type_size="1" nature="0" inner="1" tooltip="Signal sent when diagram is loaded." id="1" />
```

```
          <Input name="onStart" type="1" type_size="1" nature="2" inner="0"
             ↪ tooltip="Box behavior starts when a signal is received on this
             ↪  input." id="2" />
          <Output name="onDone" type="1" type_size="1" nature="1" inner="0"
             ↪ tooltip="Signal sent when box behavior is finished." id="3" />
        </Box>
        <Link inputowner="1" indexofinput="2" outputowner="0" indexofoutput
           ↪ ="1" />
        <Link inputowner="2" indexofinput="2" outputowner="1" indexofoutput
           ↪ ="3" />
        <Link inputowner="3" indexofinput="2" outputowner="2" indexofoutput
           ↪ ="3" />
      </Diagram>
    </BehaviorKeyframe>
  </BehaviorLayer>
  <ActuatorList model="">
    <ActuatorCurve name="value" actuator="HeadPitch" mute="0" unit="0">
      <Key frame="1" value="10.0173" />
      <Key frame="20" value="25.9256" />
      <Key frame="35" value="10.0173" />
      <Key frame="50" value="25.9256" />
    </ActuatorCurve>
    <ActuatorCurve name="value" actuator="HeadYaw" mute="0" unit="0">
      <Key frame="1" value="-0.881327" />
      <Key frame="20" value="19.158" />
      <Key frame="35" value="-0.881327" />
      <Key frame="50" value="19.158" />
    </ActuatorCurve>
  </ActuatorList>
</Timeline>
</Box>
```