Emotion-Behavior Interplay in Human Animal-Robot Interaction (HARI)

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ABSTRACT

This preliminary study investigates the emotional and behavioral responses of neurotypical (NT) and neurodivergent (ND) individuals during interactions with a robotic dog. Previous research has demonstrated the advantages of using robots and animals in therapies for autistic individuals. However, specific behaviors that elicit positive responses are not well-documented. The aim of the study is to identify these behaviors. The study involves 9 participants (NT and ND) engaging with a robotic dog in individual sessions. Pre- and post-surveys, along with interviews, were conducted to assess the participants' perceptions. Both qualitative and quantitative analyses were conducted. Results indicate significant differences in the frequency and nature of positive responses between the two groups, highlighting distinctions in the robot behaviors that evoke positive reactions. This study contributes valuable insights into the potential therapeutic and recreational benefits of robotic dogs.

CCS CONCEPTS

• Human-centered computing → User studies • Human-centered computing → Interaction design

KEYWORDS

Autism, Neurodivergent, Robot dog, Positive response

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1 INTRODUCTION

Autism has become more prevalent over the years, with current metrics showing that 1 in 36 children are diagnosed [1]. With increased prevalence, new and improved therapies are highly sought after. Autism is a spectrum consisting of pervasive developmental and neurodevelopmental differences and tends to be characterized by challenges with social interaction/communication, sensory sensitivities, and stereotyped behavior such as stimming [2]. To address these differences and help to further develop social skills and communication, many interventions have been established, including animal assisted intervention (AAI). Among many sub-branches of AAI, one of the popular methods to gain social benefits for the ND population is canine assisted intervention [3]. The main goal is to help the client better understand and manage their emotions, learn/retain new social skills, and gain educational / psychological benefits [4].

2 BACKGROUND AND RELATED WORK

2.1 Autism

Autism is a pervasive neurological developmental condition that starts before birth within the first two trimesters [2]. There are several characteristics associated with autism; however, since it is more of a spectrum everyone is affected differently. Autism can "look" many ways, and there is not just one right way to be autistic. Some of these characteristics include having restricted interests, attention deficits, difficulty with eye contact, and stimming [5]. But the most common characteristic is difficulties in social and emotional skills. Even with these difficulties in socialization it does not mean autistic individuals do not strive to socialize with others, many with autism just have differences in the way they do and may portray their emotions in a different way. We adopt the neurodiversity paradigm that wide variations in neurological development are natural forms of human biodiversity [6, 7]. This study honors the voices of neurodiverse individuals as well as the previous literature by alternating between person-first [person with autism] and identity-first [autistic person] language and using the neutral word "autism" along with the clinical term "autism spectrum disorder." The goal of this study is to help autistic individuals achieve better emotional and social experiences in their daily lives.

2.2 Animal-Assisted Intervention

There are a multitude of interventions targeted to help aid those with autism and other neurodivergence, many of which being various therapies. These include music therapy, speech therapy, vision therapy, physical therapy, and occupational therapy. An effective therapy that combines many therapy modalities is Animal-Assisted Interventions (AAI). AAI offers diverse benefits for neurodivergent individuals. AAI, a detailed and goal-oriented intervention, combines elements of various therapies, particularly occupational and physical therapy, to enhance social, cognitive, physical, and emotional functioning [8].

Dogs are commonly used in AAI due to their highly social nature and ability to communicate through verbal and non-verbal cues. They provide valuable feedback based on reactions, aiding participants in understanding the impact of their actions [5]. Dogs' playful and friendly demeanor allows them to be non-threatening and non-judgmental companions that makes social interactions more enjoyable and less stressful, unlike humans [9]. Studies suggest that autistic children comprehend non-human animal communication better than human communication, making animal involvement in therapy conducive to transferring learned behaviors into daily life [6]. Many studies report increased social interaction as a primary outcome of AAI [8]. The presence of animals serves as a social facilitator, connecting individuals with autism to those around them. Animals positively influence our perception of others and motivate us to seek further social engagement. The stress-reducing nature of animals fosters social development and reduces stimming behaviors. Children with autism often perceive greater social reward from animal faces than human faces, as animals are more appealing and less threatening [8]. These animals act as transitional objects, transferring the primary bond between the child and the animal to interactions with other humans [4]. The acquired social skills can be applied in real-life situations.

2.3 Robots and Autism

Human-robot interaction studies with social robots in the context of autism have explored their effectiveness and acceptance, revealing varying levels across different subgroups. Research indicates beneficial effects of interactions between children with ASD and robots, with some hypothesizing that autistic children empathize more easily with interactive robots than with humans due to simpler interactions. Various robot types have been studied, including humanoid, mascot, mechanical, animal, and non-humanoid categories. Humanoid and mascot robots, resembling humans, show potential for generalization but have limited engagement with autistic children [10]. Mechanical robots, resembling humanoids with visible mechanical parts, face challenges as children may focus on parts rather than the interaction [10]. Animal robots, without humanoid features, generate strong interactions with autistic children, but generalizing these interactions is difficult [10]. Non-humanoid robots, designed for specific tasks, often fail to initiate human-human interactions [10].

Social robots contribute to developing social skills in autistic children through actions such as teaching musical skills or using sign language. Some robots focus on imitation tasks, scripted interactions, and programmed feedback, promoting prosocial behaviors, improving eye contact, and reducing stereotyped behavior. Notably, using a robotic dog like the Sony AIBO in interventions has shown more authentic interactions and increased signs of affection in autistic children compared to a stuffed dog toy [11]. This authentic interaction was also carried over to the experimenters. Participants showed more signs of affection and engaged in less autistic stereotyped behavior [11].

3 RESEARCH QUESTION

In this study we investigate 2 research questions. When looking at interaction with a robotic dog for neurotypical (NT) and neurodivergent (ND) individuals: **RQ1**: What specific behaviors in robot dogs elicit positive responses from NT and ND individuals? **RQ2**: Are there differences in what elicits positive responses between NT and ND individuals? **H1:** Common behaviors of a robotic dog will elicit positive responses from NT and ND individuals. **H2**: The positive response expression will vary between NT and ND individuals.

The purpose of this study is to examine the interactions participants had with the robotic dog to understand what behaviors elicit a positive response. Our motivation is to better understand differences in preferences for a desirable robotic dog that can improve emotional / social experience for NT and ND individuals.

4 METHODS

The participants that took part in the study were tasked with interacting with a robotic dog. Their behavior and survey responses were recorded for further analysis.

4.1 Participants

Once approval was received from the IRB, total of 10 subjects were recruited and 9 participated in the study. Out of the 9 participants 7 are female (78%), 1 nonbinary (11%), and 1 male (11%). The ages ranged from 20 to 49 with the average age being 25 years old. 4 of the participants are neurotypical, while 5 of the participants are neurodivergent (4 are autistic, 1 has ADHD). The participants were recruited from a university campus through email, word of mouth, and online group forums for autistic individuals. Each participant was given a $30 gift card.

4.2 Robot

The Aibo robot was used for this study. Aibo is an AI-driven robotic pet from SONY that mimics real dog behaviors. They are equipped with cameras, sensors, microphones, speakers, and other technologies for interacting and monitoring the environment. Aibo autonomously navigated its surroundings, moving around and actively awaiting commands to respond dynamically in various interactions. Aibo has a set of commands that it can follow according to its pre-programming. Aibo can also perform tasks on its own without a verbal command given.

4.3 Procedure

The participants took part in individual sessions for the study. In each session the participants were given an informed consent form to read and sign before starting. The participants then filled out a pre-interaction survey to get some demographic data, as well as their preconceived notions regarding dogs and robots prior to interacting with the robotic dog using Likert scale questions. After the survey, a small interview was conducted to get elaborate responses on their experience with animals and robots. Once completed, the participants are then introduced to the robotic dog, given a storyboard to follow along, as well as a list of its commands. The interactions lasted around 10 minutes and participants would go through some pre-set behavior scenarios then were free to interact however they wanted. The pre-set scenarios include walking (calling the robotic dog over to them), chasing (having the robotic dog follow them), fetching (playing "fetch" with the robotic dog), performing tricks (telling the robotic dog to sit, lay down, and shake hands). Once the interaction is completed, the participants fill out a post-interaction survey to see if their perceptions changed after interacting with a robotic dog. Then a small post interview was conducted to get elaboration on their perception, identify what aspects of the interaction elicited a positive response, and understand what they like and disliked in the robotic dog for future optimization.

4.4 Measurements

4.4.1 Qualitative measures. The positive responses from participants were gathered from their interview question responses and from video during interaction. The interview questions allowed them to elaborate on why certain behaviors, features, and/or characteristics of Aibo elicited a positive reaction in them. The videos were analyzed using Behavioral Observation Research Interactive Software (BORIS) to mark when positive reactions were detected and what behavior elicited said reaction.

4.4.2 Quantitative measures. The surveys contained Likert scaling questions to determine their perceptions on animals and animal robots before and after interacting with Aibo. These results were then compared to each other to see how perception changed.

5 DATA ANALYSIS

To analyze the positive expression differences between the NT and ND groups, a Fisher Exact Test was performed to compare the frequency of behaviors for each group and each behavior category. The analysis feature of BORIS was also used to graph the interaction plots to visualize the participants' positive responses to Aibo's behaviors. The filtering analysis in BORIS was used to determine overlaps in positive responses and Aibo behaviors to show which behaviors elicited the most positive reactions. To analyze the changes in perception of robots/robot dogs, the pre-/post-survey results were analyzed with ANOVA.

6 RESULTS

6.1 Qualitative Results

When asked about favorite interactions, 44% of the responses relate to the emoting of Aibo, whether performed on its own or in response to their interaction with it, such as *petting Aibo*. The reasoning tended to deal with the resemblance to real dogs and how they act during interactions. 22% of the responses relate to Aibo playing with its toys, especially *picking up bones*. The reasoning generally related to the participant being impressed in Aibo's capability. 22% of the responses related to Aibo dancing/singing. The reasoning related to it being a unique robotic behavior since real dogs usually cannot dance and the participant feeling "loved". 22% of the responses related to the tricks Aibo can perform, specifically responding to being called over. The reasoning was the participant feeling like they had a connection with Aibo. When asked about which feature or behavior elicited the most positive response from the participant, the answers were like their favorite interaction answer with some differences. 33% responded with Aibo's emoting when pet. 22% responded with the spontaneous nature of Aibo and its ability to act on its own without commands. 22% responded with dancing behavior. 11% responded with Aibo's playful demeanor. 11% responded with the tricks Aibo can perform, specifically its variations of giving paw/shaking hand. 11% responded with Aibo's vocalization features, such as barking and whining.

6.2 Quantitative Results

The results of the Fisher Exact Test in **Table 1**, show the difference between the NT and ND groups for each behavior. There was *statistical significance* (p-value<0.05) in 4 out of the 6 positive responses between the two groups. The odds ratio shows how much more or less frequently the behavior occurs in one group compared to the other. The results of the ANOVA also show a *statistically significant difference* (p-value<0.05) according to the group factor. However, no significant difference was found over time from the pre- and post-survey responses on perception.

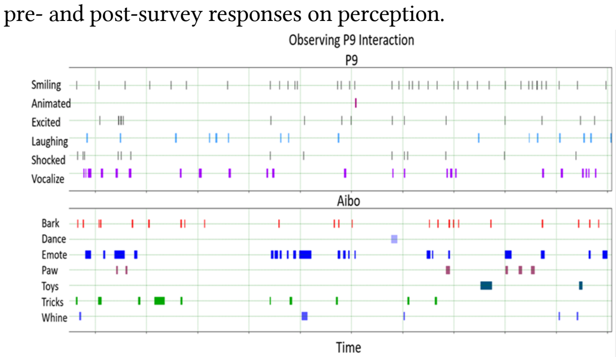

Figure 1: Typical interaction plot of the participant's responses (top chart) and Aibo's behaviors (bottom chart).

The analysis of the interaction plot in **Figure 1** shows what positive responses occurred during various Aibo behaviors. Overall, for both groups, it is observed that the emote behavior elicits the most positive reactions. The two behaviors that elicit the most positive responses in the NT group are behaviors with the toys and emoting. The two behaviors that elicit the most positive responses from the ND group are emoting and behaviors with tricks (commands i.e. "*sit*," "*laydown*," "*come here*," and "*follow me*").

Table 1: P-values and odds ratio of Fisher Exact Test.

Positive Response	P-Value	Odds Ratio
Smiling	**0.00313**	**1.75877**
Animated	**0.00059**	**5.66667**

Excited Face	**0.01439**	**0.44061**
Laughing	0.39567	0.78894
Shocked Face	**0.03335**	**0.34517**
Vocalize	0.33478	0.77454

Table 2: Number of positive responses performed by each group (NT, ND) during interactions.

Group	Behaviors					
	Smiling	Animated	Laughing	Excited	Shocked	Vocalize
NT	85	13	12	27	5	27
ND	126	5	51	67	28	68

7 DISCUSSION

7.1 Neurotypical vs Neurodivergent

Overall, the groups have a significant difference in the frequency of positive responses to Aibo. The ND group generally had more frequent positive responses for most of Aibo's behaviors. Not only were there differences in frequency of positive responses, but there were also differences in which behaviors elicited those positive responses. Overall, Aibo's "emote" behavior is described as actions for Aibo to express "emotion." She can act playful, excited, sad, frustrated, etc. "Emote" differs from other behaviors as these are a set of behaviors that are used to express emotion and personality which can overlap with other behaviors. The "emote" behavior likely elicited the most positive responses out of all participants as this is one of the features that makes Aibo appear like a real dog. These emotions are reactions to the interaction done to Aibo, such as petting, calling it a "good girl", and being able to complete a task. Aibo also does the emoting on its own when it is lonely, wanting attention, or just "bored". All these situations mimic the action and response pattern of real dogs which brings a sense of comfort and familiarity as all the participants have interacted with real dogs before. As for the behaviors that elicited the second most positive responses from each group, the NT group were more fascinated with the capability and impressiveness of Aibo being able to do the activities with the toys, such as picking up the bone or kicking the ball. On the other hand, the ND group's second behavior is "trick". This could be due to the positive reinforcement of giving a command and having it be validated by Aibo performing the behavior. For many ND individuals, rejection sensitivity (an intense reaction to real or perceived rejection) is very common and tends to have difficulties with assertiveness. Having Aibo listen and follow their command can be reassuring and feels like Aibo accepts them. One of the ND participants even said that when Aibo followed the "look at me" and "come here" command, they "felt like they had a connection."

7.2 Positive Responses and Aibo Behaviors

An interesting observation from participants was the divide in whether they liked the spontaneity of Aibo and its unexpected sequence of behaviors at times versus liking perfect responses. Some participants really enjoyed the imperfect sequencing of events when Aibo would do its own action even when it was not commanded to do so and go off randomly. They said the spontaneity helped to add to it feeling more realistic. Other participants felt that Aibo did not listen very well and would not always respond to commands or be very delayed. At times, even becoming slightly frustrated with Aibo. Potentially, finding a good balance for a future robotic dog would be most optimal. This could be done by making a mode where Aibo has more accurate performance of behaviors to commands and a normal mode where Aibo can act more spontaneously.

7.3 Limitations

An evident limitation is the small sample size, as there were only 9 participants in the study. Another limitation for data collection is the discrepancy in group populations (5 ND and 4 NT participants, respectively). There were also some discrepancies in interactions as Aibo's actions are unregulated. Since it was not a sequenced event or wizard of oz set up, the interaction was dependent on how well Aibo listened to the participants and performed during the interaction. Some interactions worked very well, and Aibo listened to almost every command. In other sessions Aibo did not listen as well so the participants did not get the full effect of the interaction. Lastly, the participants had individualized interactions, some only did the provided scenario activities while others did more of the optional interactions and got to experience more of Aibo's features. These differences in interaction quality could have influenced the number of positive responses observed. While this could affect the frequency in some ways, all the participants showed positive responses throughout their interaction and interviews.

7.4 Future Work

Next steps for this study include adding a group session design to the study. The participants will have individual andn group sessions to see if there are changes in expression, frequency, and quality of positive responses in 1:1 interaction with a robotic dog versus in a group setting. Another step would be conducting the study with other versions of robotic dogs to get a better understanding of what specific aspects elicit positive responses and would make for an optimal dog. Lastly, recruiting a larger subject pool would help us better generalize the data found.

8 CONCLUSION

In summary, this study explores the responses of neurotypical (NT) and neurodivergent (ND) individuals to a robotic dog, focusing on Aibo. The goal was to identify behaviors eliciting positive responses and differences between the groups. Key findings indicate that Aibo's emoting, play with toys, dancing/singing, and performing tricks were significant factors. Notably, there were differences in preferred behaviors between NT and ND groups, with emoting and toys more favored by NT participants, while ND participants leaned towards emoting and trick-related behaviors. The study underscores the importance of nuanced preferences in robotic dog interactions and provides insights for personalizing and providing user-centered canine-assisted interventions for diverse populations.

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