

Teleoperation Interface Usage in Robot-Assisted Childhood ASD Therapy

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ABSTRACT

Therapist-operated robots can play a uniquely impactful role in helping children with Autism Spectrum Disorder (ASD) practice and acquire social skills. While extensive research within Human Robot Interaction has focused on teleoperation interfaces for robots in general, little work has been done on teleoperation interface design for robots in the context of ASD therapy. Moreover, while clinical research has shown the positive impact robots can have on children with Autism, much of that research has been performed in a controlled environment, with little understanding of the way these robots are used “in the wild”. We analyze archival data of therapists teleoperating robots as part of their regular therapy sessions, to (1) determine common themes and difficulties in therapists’ use of teleoperation interfaces, and (2) provide design recommendations to improve therapists’ overall experience. We believe that following these recommendations will help maximize the effectiveness of ASD therapy with Socially Assistive Robots and the scale at which it can be deployed.

KEYWORDS

Socially Assistive Robotics, Autism, Social Skills Training, Case Studies, In-the-Wild Studies

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1 INTRODUCTION

Socially Assistive Robots (SARs) have emerged as a valuable tool for therapeutic and mental health interventions across a variety of domains involving children [17], due in part to childrens’ readiness to accept and engage with robots [11, 29]. One of the most promising uses for robots in childhood mental health interventions is in the context of social interventions for Autism Spectrum Disorder (ASD) [26], in which measurable results suggest that robots used in



Figure 1: An example therapy session with children gathered around a Misty robot. The therapist can be seen with a tablet controlling the robot. ©Fine Art Miracles, Inc.

this domain can increase children’s prosocial behaviors [5, 9, 35, 36], increase their engagement and motivation [11, 29], increase their use of spontaneous linguistic behaviors [6, 7, 13, 18, 31], and decrease stereotyped and repetitive behaviors [13, 24, 27, 32], resulting in positive effects across short-term and longer-term interventions [30].

Accordingly, vast amounts of research over the past two decades have explored the use of SARs in ASD therapy [4, 10, 16, 26] and ASD research [28, 30]. For much of this research, the goal is to develop autonomous social robots deployed into children’s homes to provide constant support over long timescales [8, 12, 31]. However, much of the work being done in the wild with robots in the context of ASD instead leverages, and relies on, teleoperated robots [2, 23]. While this is partly due to the challenge of developing autonomous robots, the *use of teleoperated robots is also a practical decision*: therapists seek to use robots not only as therapeutic aids outside normal therapy sessions, but also as tools.

From this perspective, one of the most significant challenges facing the use of SARs in ASD therapy is not the ability to make these robots autonomous, but rather the ability for therapists to effectively use non-autonomous robots. Specifically, as we will discuss in this paper, there are a number of significant usability challenges faced by therapists in the teleoperation interfaces they use to control robots during therapy (as well as the interfaces they use to author content that can be selected in those interfaces).

Teleoperation interfaces themselves have of course been a topic of interest within the HRI literature for several decades [33], with work in this space ongoing, especially with relation to accessible design [14, 34], multi-robot control [20, 21], and immersive AR/VR

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control [1, 3, 19, 22]. However, there has been little work examining teleoperation interfaces for SARs, despite the unique needs faced by teleoperators (i.e., therapists) in contexts like ASD therapy.

In this work, we analyze how SAR teleoperation interfaces are being used in the wild in ASD therapy sessions. To do so, we analyze a dataset provided by a Service Nonprofit that has regularly employed robots in their therapy offerings for seven years, with over 200 children in classroom settings and thousands in public outreach programs. Our analysis reveals fundamental challenges for existing teleoperation interfaces being used in this space.

2 THERAPEUTIC CONTEXT

To understand the way that robot teleoperation interfaces are being used in robot-assisted ASD therapy, we collaborated with Fine Art Miracles (FAM)[15]. FAM is a non-profit service organization serving vulnerable populations, especially children with Autism Spectrum Disorder (ASD). FAM uses creative expression and SARs to cultivate children with ASD’s communication, decrease their inhibition, and increase their attention span, engagement and overall well-being.

When FAM commenced its use of SARs in the context of ASD seven years ago, it did so by conducting a small social skills pilot. Based on the success of the pilot in demonstrating increases in attention span, verbalization, and self-regulation, FAM adopted this offering into their core services.

2.1 Therapist Workflow

FAM’s therapists use SARs to assist in practicing therapeutic interventions. From the therapist’s perspective in controlling these robots, there are two phases that occur; authorship, and interaction. Therapists author the vast majority of the speech and emotional expression options that the robot will use ahead of time. In the *authoring* phase, therapists create and organize dialogue options into *collections* for ease of use and to better manage lesson content, with each collection intended to hold content for a single lesson. In the *interaction* phase, teleoperators (usually therapists) select a collection in order to display the dialogue options within that collection, then select the dialogue options they want the robot to express. Teleoperators are also able to create new dialogue options on the fly during a session.

2.2 System Interface

FAM currently uses the open source PEERbots[25] software for therapist teleoperation of robots. A single interface enables both authoring and teleoperation capabilities, as shown in Fig. 2. This interface can be used to create dialogue options, organize them into collections, save, load and email collections, connect to a robot, and control the expression and speech of the connected robot.

3 ANALYSIS

To understand how therapists are using these interfaces in practice, we explore an archive of data collected during therapy sessions. FAM had collected the data during 8-week sessions with two groups of 6-9 year old children with ASD. We had no input into the information to be collected or influence over the design of the system used. Analysis of this data was in line with the agreements entered



Figure 2: The interface used for the therapy sessions broken up as: 1) Collection management on the left, 2) Dialogue option selection in the center, 3) Dialogue option editing and details on the right, 4) Robot connection at the bottom, and 5) Robot motion control at the bottom right. ©PEERbots

into by therapists and users, and exempted by a Human Subjects Research board. Two main types of data were provided: (1) collections of dialogue options authored by therapists and (2) session logs showing what options the therapist selected and the duration between selected options. These session logs were collected in two main contexts: (1) live therapy sessions between therapists and one or more children (discussed in Section 3.3), and (2) practice / authoring sessions in which the therapist is not interacting with children (discussed in Section 3.4). Given the way session logs were collected, if a therapist was practicing or authoring content immediately before or after a session, that content is considered a part of that session’s log.

3.1 Thematic Analysis

To analyze this archival data and identify patterns of use, we began by extracting all unique robot dialogue options across both the authored collections and the session logs. 509 unique dialogue options appeared across authored collections, and 484 unique dialogue options appeared across all session logs.

3.1.1 Coding Procedure. After identifying the set of unique dialogue options, we coded these unique options in order to sort them into discrete categories. To do so, we began by performing a shallow read through all collections to gain a baseline awareness of the space of dialogue options appearing throughout the dataset. Next, we considered the *perceived intent* of each dialogue option, with a focus on illocutionary and perlocutionary focus, i.e., the type of dialogue move each dialogue option represented, and the high-level communicative goal that seemed most likely to serve as the motivation behind the selection. As an illustration, we present two dialogue options from the "Self-Regulation Complex Emotions" collection, and their associated perceived intent:

- "does anyone know what guilty means" - a question, on the lesson topic, requesting engagement from children.
- "good job" - a comment, providing feedback, praise

Next, we enacted a clustering procedure, in which we grouped the dialogue options based on identified themes that connected their perceived intents. This produced five primary themes representing fundamentally different kinds of content appearing in the dataset: (1) Rapport-building, (2) Lesson content, (3) Feedback, (4) Attention management & Redirects, (5) Ignorance/Lack of Programming. Below, we explain the type of content observed in each of these thematic categories, and the circumstances in which we observed them being used.

Rapport-building content includes dialogue such as "Hey <name>, how are you?", "How's everyone doing?", "What did we do last time?", and "That was fun, I can't wait to come back". This type of content is primarily used at the beginning or end of sessions, and is intended, in part, as a means of modeling good social skills practice. A subset of Rapport-building can be considered lesson review and establishing common ground.

Lesson content includes informative content that therapists want to share, questions they want to ask to stimulate and encourage learning, and the follow-up responses they may have with regards to a lesson topic. Lesson content is the primary type of content that differs across authored collections. Lesson content includes dialogue options such as "how about some other words for proud".

Feedback includes both praise, such as "Great job", and corrective feedback, such as "I don't know about that".

Attention management & Redirects are a key part of managing an interaction with children with ASD. Attention management dialogue options include "eye don't think that is on topic."¹, and "Is it your turn?". Therapists have organized several of these dialogue options in a specific collection called "Redirects". The decision to create collections devoted to this single category highlights its importance and the need to have options within this category readily accessible across different types of lessons.

Ignorance or lack of programming responses included options such as "That's a good comment let me think about that" and "Good question let me think about that". We expect that these were designed for cases in which a child says something for which the therapist lacks a pre-authored response, and either does not wish to author a new response on the fly, or is explicitly seeking to buy time to author such a response.

By categorizing all dialogue options into these themes, we are able to compare the proportion of each theme. Figure 3 shows the proportion of each theme in authored collections and content expressed during sessions.

3.2 Patterns within Authored Collections

After completing our thematic analysis, we used these themes to guide a deeper analysis of the collected dialogue options appearing in collections, revealing a number of patterns both across and within each theme. We performed this analysis by analyzing the collection names, then the collection contents, then the use of themes within connections, and finally the use of themes between collections.

¹The chosen spelling of the speech here is later discussed in Section 3.4

Proportion of Dialogue Belonging to Each Theme

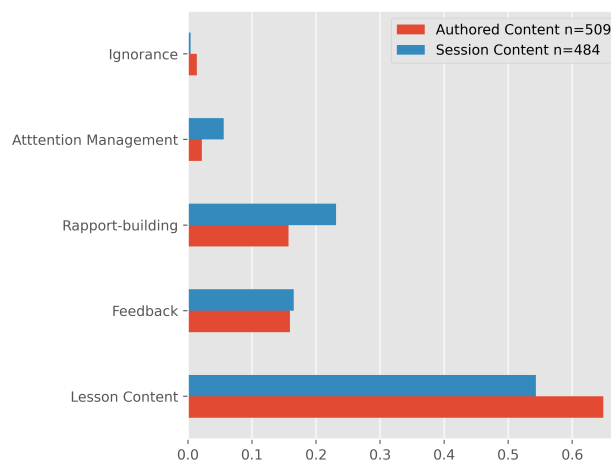


Figure 3: The proportion of themes of the dialogue options as defined following Section 3.1.1.

3.2.1 Collection Naming. To begin, we first analyzed the names of the collections themselves. The naming suggests that, with the exception of a few key collections such as "Redirects" as discussed before, most of the collections did have names that aligned with lesson topics (as intended), e.g. "Teamwork", "Intro to Social Skills" or "Taking Turns". We also find that they are all dated which may mean that collection authors create custom collections for each lesson, including a date in all collection names (likely the intended date of use) to help track collection creation in the absence of formal version control.

3.2.2 Natural Flow in Authored Dialogue. Next, we sequentially considered dialogue options within each authored collection. We observed a natural flow of speech, for example, the "Self-Regulation Complex Emotions" collection has the following dialogue options in order: "hi everybody", "today we're going to talk about complex emotions", "who remembers the discussion we had about the types of emotions that everyone feels", "happy", "sad".

The dialogue options following those shared above continue to list other emotions, ask questions about more emotions, ask the children to describe these emotions and give examples of when they've felt this way before. From this pattern, it seems clear that when authoring this collection, the therapist was likely authoring dialogue options to follow a particular imagined lesson flow. This natural sequencing of the dialogue options within the collection is likely useful for running the session since the system retains the order in which dialogue options were authored.

3.2.3 Dialogue Option Duplication. Next, we analyzed the dialogue options within and between collections, and their relation to our thematic categories. Within a single collection we typically found duplicate dialogue options that describe the same perceived intent. This is most noticeable with Feedback dialogue options. Within the same collection we may find "great" and "good job" right after

each other. Later in the same collection we find "awesome". These options are often in close proximity to and usually after dialogue options that are asking children a question like "Who can tell me what social skills are?". Duplication of these options is present with both positive and corrective feedback as well as Rapport-building dialogue options.

In addition to duplicates within collections, we also find duplicates across collections. This is most common with Rapport-building and Feedback prompts. While not exact content duplicates, they seem to be expressing the same sentiment. This inter-collection duplication is likely the result of therapists holding to the intended one-collection-per-lesson use pattern.

3.2.4 Dialogue Architecture Based on Content Category. By reading through authored content and taking into consideration the theme to which each prompt belongs, we find that there are different architectural patterns in session narrative. Content that is coded as Rapport-building provides more open ended questions and has multiple responses for each question. For example, with a question like "how are you today?", the author has added a few responses afterwards such as "that's tough", "awesome", "fantastic", "tell me more" which account for a variety of responses. For lesson content, there seems to be a direction in the conversation that the author is intending. The content authored does not appear to have the capacity to support responses from children outside of the lesson topic and the content intended to be delivered. Handling those responses may be the role of another collection of dialogue options.

3.3 Patterns within Session Logs

After analyzing the dialogue options within collections, we proceeded to analyze the way those dialogue options were used within session logs. Session logs contain metadata about the dialogue options chosen by the therapist but most importantly provide the order in which therapists use dialogue options, and the time between dialogue option selections. From this data, we evaluate the therapists' usage of the system to identify patterns and themes.

3.3.1 Session Structure. Analysis of intra-session structure through the lens of our thematic categories revealed that many sessions' dialogue options follow a multi-phase structure. Sessions generally have a core section of Lesson and Feedback dialogue options and end with Rapport-building dialogue options. A subset of those may start with Rapport-building dialogue options as well. To summarize, this shows that a typical session structure begins with greeting and checking in, followed by a lesson focusing on a specific topic, and concluding with some form of rapport building and acknowledgement. This is consistent with research on conducting therapy with children with ASD using robots [7].

3.3.2 Frequency of switching between collections. Analysis of the inter-session structure reveals that therapists use a median of 6 different collections per session. Therapists will switch between various collections during a session.

3.3.3 Options are rarely selected twice. Analyzing therapists' selections of dialogue options during a session, we observe that they don't often select a dialogue option twice within a session. Instead,

we observed a general intentional direction of conversation determined by the therapist similar to our description in Section 3.2.2. Exceptions to this norm occurred in several key cases. When providing feedback, for example, therapists often repeated a previously used option, as well as when asking a question to get more answers about the lesson content from the children's perspective.

3.4 Patterns within Authoring Session Logs

Finally, we analyzed the data from 11 authoring sessions that were logged by therapists prior to them running a session with children. In these sessions, the logs tracked therapists' interaction with the dialogue options in the collections that they are authoring, following the same format as the session logs. Whenever a therapist clicks a dialogue option, the system creates a log as if the therapist had requested that option be spoken by the robot.

By investigating authoring session logs, we find that therapists test grammatical variations of the same content, likely to determine how the robot pronounces them. They also test different variations of spelling for children's names, likely to make sure that the robot pronounces them correctly. Therapists reuse the potentially misspelled name across multiple dialogue options. We find that therapists also create custom greetings for each child.

4 DISCUSSION

While robots have been shown to be effective at helping children with ASD acquire social skills, the interfaces that operate these robots are often lacking. Robot teleoperation interfaces are generally designed to control robots but not necessarily in the context of therapy for children with ASD. Despite that, FAM has had success in running therapy sessions over the last 7 years.

From FAM's archival data, we were able to identify key patterns unique to SAR therapy such as: content categories, the repeated structure of a session; building rapport and establishing a context, covering a lesson topic then concluding with a greeting, and the importance of feedback in every session. Based on the patterns we've identified, we are able to make the following preliminary recommendations for dialogue authoring and teleoperation systems:

- R1** Authoring and Teleoperation interfaces for dialogue should have custom views for each content category, and simplify switching between them.
- R2** Teleoperation interfaces for dialogue should be able to handle dynamic dialogue content so that teleoperators can easily customize the content to different individuals.
- R3** Teleoperation interfaces for dialogue should present suggested options that a therapist may want to select based on previously selected options.

We outline these design recommendations as future work to investigate by interviewing therapists and studying various implementations' impact on therapist usage.

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