Analyzing Teleoperation Interface Usage of Robots in Therapy for Children with Autism

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Therapist-operated robots can play a uniquely impactful role in helping children with autism 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 therapy for children with autism. 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 practice. 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 therapy for children with autism when using Socially Assistive Robotics and the scale at which robots can be deployed in this domain.

Additional Key Words and Phrases: Socially Assistive Robotics, Autism, Social Skills Training, Case Studies

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1 INTRODUCTION

Socially Assistive Robots (SARs) have emerged as a valuable tool for therapeutic interventions across a variety of domains involving children [23], due in part to children's readiness to accept and engage with robots [16, 36]. One of the most promising uses for robots with children is in the context of social interventions for children with autism (CWA)[1] [33]. Researchers have demonstrated measurable results suggesting that robots used in this domain can increase children's prosocial behaviors [8, 14, 45, 46], their engagement and motivation[16, 36], their use of spontaneous linguistic behaviors [9, 10, 19, 25, 39], and decrease stereotyped and repetitive behaviors [19, 31, 34, 40], resulting in positive effects across short-term and longer-term interventions [38]. While these effects are a crucial step, robots as a therapeutic tool exist in a vast space of therapeutic modalities run by humans. Robot-led therapy with CWA has been shown to produce

[1]There is disagreement on the terms to use to describe autism [24]. Throughout this paper we will use the terms autism and children with autism.

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similar *learning outcomes* compared to a human therapist [42]. However, studies have shown that CWA, specifically, are *more receptive* to a robot compared to a human [13, 17].

Accordingly, many researchers have explored the use and development of SARs in therapy for CWA [7, 15, 22, 33] and autism research [35, 38]. For much of this research, the goal is to develop autonomous social robots that can be deployed into children's homes to provide constant support over long timescales [12, 18, 39]. However, much of the work being done in practice instead leverages, and in fact relies on, teleoperated robots [4, 30]. Movia Robotics[37], for example, offers a semi-autonomous teleoperated system along with in-house created content and experiences.

While the use of teleoperated robots is partly due to the challenge of developing autonomous robots, it is also a practical decision: therapists need to stay in the loop throughout therapy with children due to the sensitive nature of the interaction. From this perspective, one of the most significant challenges facing the use of SARs in therapy for CWA 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 been a topic of interest within the HRI literature for several decades [43], with work in this space ongoing, especially with relation to accessible design [20, 44], multi-robot control [27, 28], and immersive AR/VR control [1, 5, 26, 29]. However, there has been little work examining teleoperation interfaces for SARs, despite the unique needs faced by teleoperators (i.e., therapists) in contexts like therapy for CWA. Moreover, the vast majority of previous work on robots for CWA has examined robots deployed in a research context, through small-scale laboratory experiments [13], or, in rare cases, field deployments of robots by researchers into school [10] and home environments [11, 39]. In contrast, there has been little, if any, work examining how therapists use SARs as part of regular therapy sessions for CWA (i.e., divorced from any research context), and what challenges they may be facing. There is a need to (re-)align research studies in SAR interventions for autism with evidence-based clinical standards and the realities of clinical practice [2, 3].

(a) 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.

(b) A soft bot interacting with children. The current interface presented on the tablet is the robot face that is controlled by the teleoperation interface. ©Fine Art Miracles, Inc.

Fig. 1. Examples of children interacting with the different robots therapists teleoperated.

In the context of robot-assisted therapy for CWA, teleoperation is the control of a robot's utterance and motion. In this work, we analyze the dialogue authored within and uttered through a SAR teleoperation interface used in practice in therapy sessions for CWA as shown in Fig. 1. 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 work reveals fundamental challenges for existing teleoperation interfaces being used in this space. Based on our analysis, we suggest a number of concrete recommendations for how interfaces used by therapists for both robot teleoperation and content authoring should be adapted. We believe that making these suggested interface adaptations will not only improve the effectiveness of robots used in these cases, but also improve the scale at which content can be authored and at which SARs can be deployed.

2 THERAPEUTIC CONTEXT

To understand how therapists use robot teleoperation interfaces in robot-assisted therapy for CWA, we collaborated with Fine Art Miracles (FAM) [21], a non-profit service organization serving vulnerable populations, including CWA. FAM conducts recurring 8-week programs for children with special needs at their schools. Each week, a therapist uses a SAR to teach children in a 45 minute session. Sessions cover establishing relationships, greetings, modeling rapport, friendship making, and social skill modeling and practice. Three key components to understand about these sessions are the therapists' workflow, the robots used in these sessions and the teleoperation interface that controls them.

Therapist Workflow: Within each session, the therapist sits with children in a circle (as shown in Fig. 1a) and controls the robot's dialogue. The therapist selects from the available options and the robot verbalizes the selected option. To ensure that the necessary options are in fact available during the session, therapists must spend time *before the lesson* authoring the session content.

Socially Assistive Robots Used: Two different types of robots are used in the therapy sessions, the Misty robot from Misty Robotics (Fig. 1a) and custom Softbots (Fig. 1b).[2]

System Interface: A single interface (shown in (Fig. 2)) is used by FAM for authoring and teleoperation capabilities,. This interface is the PEERbots[32] open source software 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 THEMATIC ANALYSIS

To understand how therapists use the interfaces in practice, we explore an archive of data collected during therapy sessions. This dataset was provided by FAM, who had collected the data of a therapist's usage during 8-week sessions with two groups of 6-9 year old CWA. 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 into by therapists and users, and exempted by a research ethics board as described in section 7. Two main types of data were provided: (1) collections of dialogue options authored by therapists and (2) session logs showing the options the therapist selected (for the robot to verbalize) and the duration between them. A dialogue option is a sequence of words authored by an end user intended to be verbalized at the push of that button. 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. 512 unique dialogue options appeared across authored collections, and 486 unique dialogue options appeared across all session logs.

3.1 Coding Procedure

To conduct our thematic analysis[6], an initial coder (IC) 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, they considered

[2]The Softbot is a derivative of the open-source family of robots from Romibo [41] fabricated in small volumes for FAM and is not a commercial product.

Fig. 2. The system interface used for the therapy sessions. (Note: content presented is for demonstration purposes. Actual therapeutic content used by the nonprofit is proprietary.) The interface is broken up as follows: *1) Collection management* - The left hand side shows the dialogue options collection management in the form of loaded collections and ability to save and load them. *2) Dialogue option selection* - The central section shows the available dialogue options from the selected collection. Clicking them triggers that dialogue option to be spoken by the connected robot. Clicking a button also selects it in the editing section. *3) Dialogue option editing* - The right side shows the last selected dialogue option with the ability to modify the button's name, dialogue spoken, face color, and facial expression. An example of the face is shown in (Fig. 1b). *4) Robot connection* - The bottom section presents the ability to connect to a robot. *5) Robot motion control* - The bottom right portion of the interface allows the therapist to move the robot. ©PEERbots

the *perceived intent* of each dialogue option. For example, "does anyone know what guilty means" asks a question on the lesson content, while "good job" provides feedback on a child's performance or action. IC enacted a clustering procedure, in which they identified and defined initial themes based on perceived intents. Afterwards, 2 additional coders were recruited, and all coders labeled each dialogue option based on the most appropriate theme defined by IC. When coders were labeling the data, all content was presented in its authored or used order. This is crucial, since the context in which these options are used is essential to understanding their intent. Due to the nature of sessions teaching social skills, coders found it confusing to determine whether a dialogue option was part of a lesson or whether it was establishing rapport had they not been aware of adjacent dialogue options.

After the initial coding round, coders were in moderate agreement ($\kappa = 0.763$). Coders then discussed the disagreed upon dialogue options and updated theme definitions. Coders concluded that the initially identified themes were sufficient but required clarification due to a potential overlap in coverage. While there was overlap, the distinct attributes of overlapping themes were important enough to keep separate. Using the updated definitions, the coders re-labeled all the data resulting in strong agreement ($\kappa = 0.842$). There were 19 records with a lack of any agreement between coders and 167 records with 1 coder disagreeing. Records that lacked any agreement were discussed and consensus was determined as a group. For the remaining records, we used the majority voted code.

3.2 Identified Themes

We identified five primary themes representing different kinds of content appearing in the dataset:

- **T1 Rapport-building** is content used to introduce people, ask how they're doing, establish rapport and context, wrap up, and end an interaction. This 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 a session, and is intended, in part, as means of modeling good social skills practice. A subset of rapport-building is closely tied to previous lessons and can be considered lesson review and establishment of common ground. This type of content is typically followed by lesson content.
- **T2 Lesson content** is informative content, interventions, or activities that therapists want to share, questions they want to ask, and the follow-up responses they may have after the children respond relating to the topic or lesson. Lesson content includes dialogue options such as "how about some other words for proud".
- **T3 Feedback** responses are positive or negative judgement responses that aim to give feedback including praise and criticism such as "Great job", and "I don't know about that".
- **T4 Attention management** content focuses on regulation and regaining children's attention. Attention management dialogue options include "eye (sic) don't think that is on topic."[3], 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 these options readily accessible across different types of lessons.
- **T5 Ignorance** responses are those that are useful when a child says something that may not have a response that the therapist has already authored. These responses included "That's a good comment let me think about that" and "Good question let me think about that".

Coders labeled dialogue based on the most applicable theme. For example, while "I don't think that is on topic" may be considered feedback, since the intention is to redirect the child back on topic, it was labeled as attention management.

4 IDENTIFIED PATTERNS

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 analyzed authored collections and session logs separately to identify any patterns that are unique to each process. Figure 3 shows the proportion of each theme in authored collections and content expressed during sessions.

4.1 Patterns within Authored Collections

In this section we discuss patterns that exist relating to authored collections based on the themes to which dialogue options belong. Collections are the groupings of content as *defined by the therapist*. We investigated patterns within collection names, the order in which dialogue options were authored, and duplication within and across collections.

4.1.1 Collection Naming. We first analyzed the names of the collections themselves. All collections are named based on lesson topics, e.g. "Teamwork", "Intro to Social Skills" or "Taking Turns" with the exception of "Redirects" which contained most of the attention management content. We also found that collection names are all dated which may

[3]This spelling is an artifact necessitated by the robot's text-to-speech software.

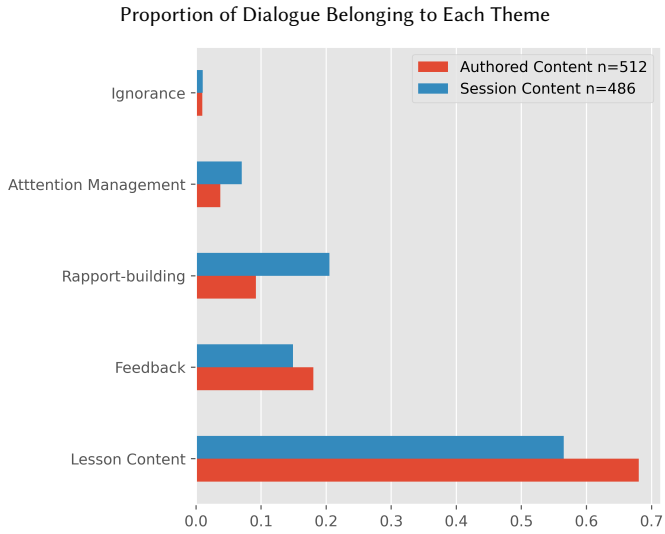

Fig. 3. The proportion of themes of the dialogue options as defined in Section 3.2.

mean that collection authors created them for particular sessions. Including a date in all collection names (likely the intended date of use) could help track lesson content creation in the absence of formal version control.

4.1.2 Authored Order of Dialogue Options. Sequentially analyzing authored dialogue options within individual collections through the lens of our thematic annotations revealed noteworthy patterns within and between themes. Collections generally (with the exception of "Redirects") begin with rapport-building content, followed by lesson content with interspersed feedback content, and conclude with rapport-building content. This pattern is likely the author's intended use for the collection since it follows a structure that eases into and out of lesson content to begin and end a session.

When analyzing each theme, we find that content that is coded as rapport-building contains open ended questions. For example, with a question like "how are you today?", the content that follows accounts for a variety of responses: "that's tough", "awesome", "fantastic", "tell me more". Whereas with lesson content, the dialogue does not have the capacity to support responses outside of the intended lesson topic and instead only includes simple positive or critical feedback when questions are asked. Feedback, attention management, and ignorance content do not have follow-up responses since we would expect them to be used in between other themes. In other words, after the robot has provided feedback, we would expect it to move on with the lesson or switch to rapport-building.

4.1.3 Dialogue Option Duplication. Next, we analyzed the dialogue options within and between collections, and their relation to our identified themes. Within each collection we found 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 in close proximity to and usually after dialogue options that ask children a question like "Who can tell me what social skills are?". In addition to duplicates within collections, we also found duplicates across collections most commonly with rapport-building and feedback prompts. While not exact content duplicates, these cross-collection duplicates express the same sentiment.

4.2 Patterns within Session Logs

After analyzing the dialogue options within collections, we proceeded to analyze the way those dialogue options were *actually used* within sessions by a therapist. Session logs contain metadata about dialogue options and more importantly provide the order in which a therapist used the dialogue options, and the time between selections.

4.2.1 Session Structure. Analysis of intra-session structure through the lens of our identified themes 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 the analyzed sessions also start with rapport-building dialogue options as well. To summarize, this shows that the typical session 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 aligns with the sequence of authored dialogue described in Section 4.1.2 and is consistent with research on conducting therapy with CWA using robots [10].

4.2.2 Lack of Repeated Selection of Dialogue Options. Analyzing therapists' selections of dialogue options, we observe that they don't often select a dialogue option more than once within a session. Instead, we observed a general intentional direction of conversation determined by the therapist similar to our description in Section 4.1.2. Exceptions to this norm occurred in several key cases. When providing feedback, for example, therapists repeated a previously used option, as well as when asking follow-up questions to get more answers about the lesson content from the children's perspective. We visualize an example session in Figure 4 showing the selection of dialogue options over time illustrating this pattern.

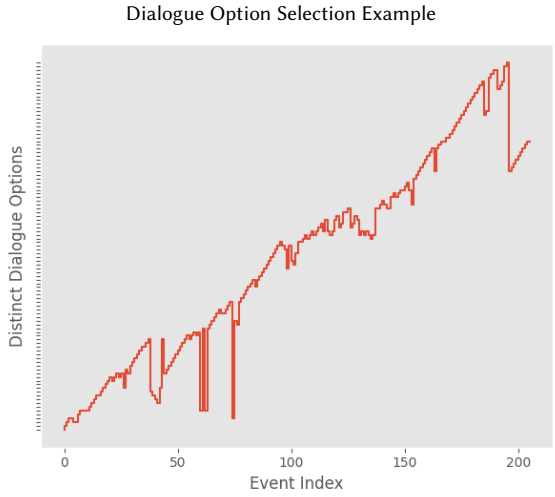

Fig. 4. An example state transition plot within one session. Y-axis ticks are dialogue options; X-axis ticks are option selections. Vertical drops show the teleoperator revisiting previous dialogue options.

5 DESIGN RECOMMENDATIONS

In this section we cover design recommendations that we believe, based on our observed use patterns, will improve the effectiveness of content authoring and robot teleoperation interfaces used in therapy for CWA. The design recommendations we propose are grounded in an overarching design philosophy that the system should be designed to make it as easy as possible for therapists to author content for sessions and run them effectively. Our recommendations are:

- **R1** Authoring and teleoperation interfaces for dialogue should have custom views for each content theme, and simplify switching between them.
- **R2** Teleoperation interfaces for dialogue should 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 the teleoperator may want to select.

5.1 Custom Interfaces For Content Themes

SAR therapy sessions for CWA follow a unique structure and distinct dialogue themes that should be accounted for. Current teleoperation interfaces focus on presenting a single collection which is optimized for delivering lesson content. We suggest modifications that take other themes into consideration. In general, creating a custom interface per theme allows for a more focused design approach that can instill therapeutic best practices for each stage in the session.

Session Structure — Since sessions follow a multi-phase structure (rapport-building then lesson content and feedback then rapport building), and each theme has a different structure (predetermined vs open ended), interfaces should provide adaptations for each phase. For example, interfaces could have a separate view for rapport-building available at the beginning and end of a session. It would also be beneficial to allow the teleoperator to quickly switch between them.

Rapport-building & Attention-management Content — Content focusing on rapport-building was the second most used dialogue type despite it being a fairly consistent style of dialogue across sessions. Teleoperation interfaces should provide rapport-building options built-in. Following the previous recommendation, having a dedicated view for rapport-building would allow for a space that takes into account its open ended nature.

Rapport-building content can follow a tree structure where each dialogue option may result in one of many options. When a selection is made, the remaining unselected options are not useful to display. Rapport-building content could be developed for teleoperation interfaces (or extracted from previously used logs) and expressed following a tree structure to better assist therapists. As can be seen in Fig. 2, there can be many options to keep track of even within a single collection. Exploiting the tree-like structure of this content theme may reduce the cognitive load of the view.

Attention-management content is already predominantly organized into a single collection. While this may work for teleoperators, it is likely a workaround and supports the idea that, similar to rapport-building, there may be benefit to having a dedicated view for content belonging to this theme.

Feedback and Ignorance Content — Given the frequency of authored (18%) and used (15%) feedback content, teleoperators should not be spending time authoring such content or considering where to place it within their collections. Instead, we recommend that feedback options always be easily accessible regardless of the selected collection. The same approach can be applied to Ignorance dialogue content. However, following the Ignorance dialogue option's selection, the teleoperator still needs to provide a follow up response. We recommend the addition of a mechanism to enable robots to express content authored on-the-fly, such as a text box with a button to speak the text without it saving to a collection.

5.2 Dynamic Authored Content

Therapists author extensive variations of the same content to customize them for different children. In addition, it is difficult to predict children's responses ahead of time. We recommend that dialogue teleoperation interfaces account for dynamic content. Authored content could include placeholders that may be modified or determined during the session. Handling dynamic content could eliminate the use of ignorance options and increase customization for each child.

5.3 Suggest Dialogue Options

To increase the ease with which teleoperators select dialogue options, we recommend adding suggested options to teleoperation interfaces. These options can be suggested based on factors relating to the last dialogue option selected. For example, if the last selection was a question, the suggestions may be for different feedback content. If the system is able to accurately predict the teleoperator's next dialogue option, it would likely ease the robots' teleoperation. Suggested options would likely reduce cognitive load and required skill to operate a robot. This could allow less experienced therapists or even parents to operate robots without significant professional training. Although it is not the goal of our work, suggestions in teleoperation could also inform the development of autonomous SARs in the future.

6 CONCLUSION

While research has shown robots to be effective at helping children with autism acquire social skills, the interfaces that operate these robots are often lacking. Robot teleoperation interfaces are designed for general cases and not necessarily for therapy for CWA. Despite that, FAM has had success in running therapy sessions over the last 7 years. From FAM's archival data, we identified key patterns unique to SAR therapy such as: content themes, the typical 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 these patterns, we are able to make three design recommendations of (1) incorporating custom interfaces for each content theme, (2) handling dynamic content, and (3) presenting suggestions based on an understanding of the content and the teleoperator's usage.

With the analysis of archival data we aimed to identify the difficulties faced by therapists in using robot teleoperation interfaces. While we uncovered some difficulties, these are likely a subset of the difficulties faced by therapists. A limitation of our data is that it only includes the dialogue verbalized by the robot with no information about what the therapist may have said or how the children responded. As future work, we plan to interview therapists to verify the patterns we've identified and learn more about their needs and experiences in robot-assisted therapy for CWA.

7 SELECTION AND PARTICIPATION OF CHILDREN

Study data was provided by Fine Art Miracles who work with schools' special education classes. Parents consented to the use of their children's data for analysis and improvement of therapeutic systems at FAM. Data used in this research is archival content verbalized by robots and/or authored by therapists, and is not content shared by children.. We did not recruit or interact with children as part of this work. An independent review board has exempted the use of this data for research purposes. Images of children in Figure 1 are property of Fine Arts Miracles Inc. Parents of the children in these photos consented for the photos to be publicly shared as part of research efforts.

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