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Therapists' Opinions on Telehealth, Robotics, and Socially Assistive Robot-Augmented Telepresence Systems for Rehabilitation

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Abstract—Shortages in therapists, along with the COVID-19 pandemic, have created a gap in care for people with cerebral palsy, stroke, and many other conditions requiring rehabilitation. Socially assistive robots and telehealth are two tools which could help fill this gap and may be able to work together, in socially assistive robot-augmented telerehabilitation, to create meaningful telerehab encounters. We present results from a survey completed between Jun 31, 2020, and Dec 31, 2020, asking 379 therapists in the United States for their opinions on features which may be useful for a telerehabilitation platform and for their general feelings towards robots. We explore their answers and reduce the response space by identifying six factors underlying the answers. We show that therapists want high quality video, control over robots, and more regulations. We also find that they are positive about the features which could be used in socially assistive robot-augmented telerehabilitation.

I. INTRODUCTION

There is an increasing shortage of healthcare workers in both urban and rural areas of the United States [1]–[3]. Technology, including telehealth and robotics, can play a role in addressing these shortages and offer clinicians new ways to treat increasing numbers of people needing care. A clinical space ripe for innovation is rehabilitation, which is experiencing shortages of workers, especially therapists, to treat and care for people living with disabilities and associated medical complications [4], [5]. This is an area of healthcare where the frequency of clinical interactions should be high to promote convalescence [6], and where interactions should continue across the care continuum from acute inpatient settings to community and home settings.

Telehealth can extend the reach of clinicians, enabling experts to reach patients who cannot get to the clinic due to travel, scheduling, or other challenges. For rehab patients, this could mean more frequent interactions with their provider, which may increase patient motivation and

adherence to at-home exercises [7]. Robotics can also extend the reach of clinicians, allowing a clinician to treat more patients with longer interactions, without an undue load on the clinician. For example, classical robotic systems in rehab for the upper extremities, many of which take inspiration from the MIT-Manus [8], interact hands-on with patients, allowing the sensing and application of force for strength building, motor learning, and stretching. These robot-assisted therapy systems have been shown to be highly effective at improving task-specific motor performance in neurorehabilitation [9].

Another target of development for robotics in rehabilitation is socially assistive robotics [10]. Socially assistive robots (SARs) can act as intelligent assistants to both patients and clinicians. SARs can communicate and interact with patients to help them in their rehabilitation activities. Studies suggest that having a physical robot to connect with is important for building trust and motivation in patients compared to virtual avatars [11], [12], and may lead to clearer communication of instructions [12], [13], yielding better therapy interactions and assessment capabilities. For example, the Nao-Therapist robot plays games with patients to motivate them in upper extremity exercises by demonstrating poses and asking patients to mirror them [14]. The RAC CP Fun is a social robot developed for young patients with cerebral palsy (CP) that plays games with them while providing verbal feedback [15], leading to high overall engagement with patients [16]. Bandit is a larger humanoid robot which has been used successfully in stroke rehabilitation [17].

Typically, an expert clinician will assess a patient to determine their functional state before, during, and after rehabilitation and work with the patient in-person, instructing them through stretching and strength building activities, providing manual manipulation, etc. These activities can be supplemented using telehealth and robotics.

More recently, the COVID-19 pandemic has exposed another use case for robotics and telehealth: infection prevention. By using a robot or telehealth platform, clinicians and their patients can be protected from the spread of infectious pathogens. As a result of changes in the regulatory environment and a need to maintain care while handling pandemic related restrictions, the use of telehealth in mainstream healthcare, including rehabilitation, has exploded [18]. Current telehealth activities are largely delivered via video. Although clinicians can perform a variety of tasks via video, including performing assessments [19], [20], doing so can be limiting and tedious. There is a need to understand how best to deliver the highest quality care remotely.

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Fig. 1. Flo, a SAR-augmented telerehabilitation platform.

The addition of a socially assistive robot to telepresence platforms may help deliver high-quality rehabilitation at a distance. To investigate this, previous studies proposed to combine these technologies into one [21], [22]. Early exploration showed that patients and clinicians are receptive to SARs augmenting telehealth. This paper presents findings from a large survey of rehabilitation therapists, which, among other topics, asked them to report their opinions on desirable features for a SAR + telepresence system, and their general feelings towards robots in healthcare. The Flo platform (fig. 1) [21], which has a humanoid robot with arms, a face, and a torso on a mobile base with a screen and cameras, is briefly reviewed in this paper and used as an exemplar SAR + telepresence system in the survey to gain insights which should be

applicable to a variety of robot morphologies. Results from this paper will serve as guidance for design features and considerations of socially assistive robot-augmented telepresence systems and robots in rehabilitation more generally.

A. Related Works

Perceived use and usability studies are common methods used in human-robot interaction to gain insight on the clinician and patient experience with rehabilitation robotics. Although useful for providing design guidance, these studies are often limited by small numbers of subjects and low diversity in the clinicians surveyed. This study is unique, with a large sample of therapists working in a variety of care settings and locations during the COVID-19 pandemic and a quantitative analysis of themes derived from their responses.

1) *Feelings Towards Robots*: We aimed to gain insight into how rehabilitation therapists feel about using robotics in healthcare. In a related work, Winkle et al. interviewed 21 therapists about how SARs can be useful in rehabilitation, how engagement can be measured, and how SARs can be tailored to specific patients [23]. Their results indicated an interest in SARs for increasing compliance, motivation, and engagement; specific use cases identified were at-home exercises for children and adults and facilitating pediatric therapy. In a larger study, A.K. Hall et al. surveyed 499 adults aged 18–98 to understand acceptance of robots and perceived usefulness for various tasks, including for healthcare assistance in different settings [24]. Their results indicated that respondents were less comfortable having robots in care-related roles such as performing a medical operation or caring for elderly patients, but more comfortable with assisting with domestic activities of daily living (ADLs) such as cleaning and taking vital sign assessments. Younger adults were more accepting of robots in hospital settings compared to older adults. They did not report significant differences between younger, middle-aged, and elderly respondents in terms of acceptance in domestic and medical tasks. Görans-

son et al. surveyed 111 healthcare professionals on their attitudes towards humanoid robots and AI for a variety of tasks [25]. Subjects responded positively to using robots for nursing activities, monitoring, telemedicine, and social communication, but negatively to using robots for caring activities unless the robot works with a human caretaker.

2) *Telepresence and SAR Features*: Additionally, we aimed to determine which features in SAR-augmented telepresence systems clinicians find most useful to guide future design. Previously, Winkle, et al. interviewed 21 therapists and found features that were perceived to be useful in SARs for rehabilitation were those that improve ease of access, e.g. data recording or exercise demonstrations, and provide motivational support, e.g. providing positive reinforcement and making exercises enjoyable [23]. Shin et al. surveyed 210 members of the robotics community in South Korea on factors that influence acceptance of socially interactive robots and found that the social presence of the robot and adaptivity were key factors for user acceptance [26].

B. Flo — An Example SAR for Telerehab

Flo (fig. 1) is designed to enhance telerehabilitation interactions by providing a physically present agent for patients to interact with. Interactions with the robot are envisioned to progress as a series of games, such as a Simon Says game or target touch activity but can be crafted per the needs of the clinician, operator, and patient. While the patient is interacting with the humanoid, the clinician can continue to interact with the patient remotely through a screen and speaker on the system. Flo’s face can dynamically change to express emotion and speech is synthesized in real time using AWS Polly. Each arm has 4 degrees of freedom to demonstrate a variety of tasks to patients. An array of cameras on the platform gathers data to enable automated assessment of patient function. The system is completely under the control of the remote clinician using a plays and scripts type model.

Presenting Flo to clinicians as an exemplar SAR-augmented telepresence system in the survey was necessary to ensure that all respondents have an appropriate level of familiarity with the class of robot being discussed and the ability to respond effectively.

II. METHODS

We distributed a 15-minute survey to therapists, physicians, and other rehabilitation professionals on REDCap [27] to gain insight into the impact of COVID-19 on the needs of care providers, opportunities for telehealth in rehabilitation, which features for telerehabilitation are useful, general feelings towards robotics, and where robotics in general may have the greatest utility in rehabilitation. This study was approved by the University of Pennsylvania Institutional Review Board. Here we report on therapists’ general feelings towards robots across multiple domains and features therapists believe would be useful for telerehabilitation, examining features both classically present in telepresence robots and

TABLE I

ABBREVIATIONS REPRESENTING STATEMENTS AND FEATURES CLINICIANS WERE ASKED TO SCORE FROM -2 (STRONGLY DISAGREE/EXTREMELY USELESS) TO +2 (STRONGLY AGREE/EXTREMELY USEFUL)

Abbreviation	Question	Abbreviation	Question
feat-mobileManual	A mobile system which can be driven remotely	feel-careFocus	Robots allow other caretakers to focus on higher level work
feat-mobileAuto	A mobile system which can drive on its own	feel-robotAccurate	Robots are consistent and accurate
feat-socialArms	A social robot with arms to augment standard video calls	feel-expensive	Robots are too expensive
feat-socialFace	A social robot with an expressive face to augment standard video calls	feel-setupTime	Robots take too much caretaker time to set up
feat-socialAuto	A social robot that can interact with patients without needing operator input	feel-unethical	The use of robots for care and treatment is unethical
feat-webInterface	A web interface for controlling remote telerehabilitation systems	feel-patientReject	Patients dont want robots to take care of them
feat-socialGames	A social robot which can play games with subjects during telerehabilitation calls to augment standard video	feel-clinicianControl	I want robots that I can control
feat-assessmentAuto	A system which collects data and performs automated assessments of patient function	feel-lostJobs	Robots are going to take jobs
feat-clearScreen	A clear screen to see the clinician	feel-robotFailure	Robots are too likely to break or fail
feat-hqVideo	High quality video to see the patient	feel-clinicianWellbeing	Robots will improve clinician well-being
feel-positive	I have general positive feelings towards robots	feel-negative	I have general negative feelings towards robots
feel-medDev	Robots are the same as any other medical/assistive devices	feel-notreatUnethical	Failing to use robots for care and treatment is unethical
feel-patientIndependence	Robots will improve patient independence	feel-damageInteraction	Using robots will damage peoples ability to interact with other people
		feel-laws	We need more laws and regulations about robots
		feel-study	We need to study more about how robots affect function
		feel-automatic	I want robots that act on their own
		feel-societyBad	Robots are bad for society

features which may be present in the newly proposed SAR-augmented telepresence systems. The complete survey, data, and data analysis can be found in the supplemental material.

A. Survey Design

Respondents were surveyed on their basic demographics: type of clinician, age, gender, practice setting, sub-urban/urban/rural locale, state and country, and years of practice. They were asked about the type of patients they treat and their experience with telehealth before and during the COVID-19 pandemic. A video overview of the exemplar SAR-augmented telepresence system, Flo (<https://youtu.be/OHybatsjz0g>) was presented, and they were asked about their previous knowledge of Flo, how interested they would be in using the system, and settings where it would be useful.

Subjects were then asked to rate the utility of features which could be used in robots and telepresence (“What features do you believe are useful in a system to make tele-rehabilitation work well”), choosing from 5 options: Extremely Useless, Somewhat Useless, Neutral, Somewhat Useful, Extremely Useful. They were also asked to assess their thoughts on robotics in healthcare (“In this section we ask for some final thoughts on robotics in healthcare”) on a 5-option scale: Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree. The list of questions for these sections is in table I with abbreviations which are used in this paper.

Respondents could opt into a \$20 gift card raffle, with one winner chosen randomly from every 20 survey submissions.

B. Survey Distribution and Data Collection

The survey was distributed via professional organizations, email lists, social media groups, and blogs. A total of 507 clinicians completed the survey between July 31 and Dec 31, 2020, 84% of whom identified as therapists, primarily in the United States. In this analysis, responses from therapists working in the United States with at least one year of experience and no prior knowledge of Flo are included (n=379).

C. Data Analysis

All analysis was performed in R using the psych, nFactors, and tidyverse packages with the tidyverse, likert, and tikzDevice packages for plotting.

1) *Data Cleaning*: The data required only minimal cleaning. One record was marked as complete but was missing most of its data and so was discarded. Therapists indicated their specialty in an open-ended question. They were sorted by their response into occupational therapist, physical therapist, speech language pathologist, and other.

2) *Exploring Responses*: Response counts for each question were calculated and discussed. Open ended responses were explored and summarized.

3) *Discovering Latent Themes in Responses*: To understand the latent themes of the responses to the questions posed on features for a telerehab robot and feelings towards robots, we performed an exploratory factor analysis. To

determine whether a factor analysis was reasonable, Bartlett's test was run on the responses from the features and feelings questions. A scree plot, along with Kaiser's Rule and Horn's parallel analysis, was used to determine the number of factors to construct. Factors were calculated using the iterative ordinary least squares method to find the minimum residual solution, allowing the factors to transform obliquely to better align to the data. A coarse scale was created, based on the factor analysis results, to assign each question to a theme. Each question was assigned to only one theme, the one on which it had the highest magnitude loading. To score each theme, the mean response of all questions assigned to that theme was calculated. This coarse method does not capture the true scores of the factor analysis, nor does it align with the bases of the factor analysis as well as more refined methods [28]. It does, however, preserve the question scale, enabling easy interpretation, and avoid the challenge of factor score indeterminacy. To evaluate internal consistency, Cronbach's alpha was computed for each theme.

To explore the overall sentiment of the respondents, the scores for each theme were evaluated for deviation from neutral (0) using the appropriate hypothesis test, two-sided, with alpha set to 0.05. Confidence intervals were calculated for the mean (parametric) / pseudomedian (non-parametric).

III. RESULTS

A. Sample Demographics

A total of 379 therapists in the United States with one or more years of experience and without prior knowledge of Flo completed the survey between June 31, 2020, and December 31, 2020. The mean age of the respondents was 40.2 years old with standard deviation 12.4 years. They had mean 14.6 years experience with standard deviation 11.9 years. The sample comprised 169 occupational therapists (OT), 154 physical therapists (PT), 42 speech and language pathologists (SLP), and 4 therapy assistants. There were 39 male, 340 female, and 0 other gender respondents. Respondents work in rural settings (74), suburban settings (215), and urban settings (154) (some respondents work in multiple locales), across a variety of clinical settings, including outpatient facilities (99), general hospitals (85), rehab centers (70), schools (54), inpatient facilities (50), elder care homes (46), private practices (40), patient homes (40), hospitals for children (10), elder care hospitals (8), and others. The largest number of respondents came from Ohio (190), followed by Illinois (47), Pennsylvania (34), New York (18), South Carolina (14), and 23 other states with fewer than 10 subjects each.

B. Question Responses

The results for the questions prompted by "What features do you believe are useful in a system to make telerehabilitation work well?" are shown in fig. 2. Respondents rated high quality video to see the patient, clear screen to see the clinician, a system which performs automated assessments of patient function as the highest features with 87%, 85%, and 75% of respondents saying they are useful. A social robot that can interact with patients without needing operator input

received both the lowest number of ratings for usefulness and the highest number for uselessness. When further asked "Please list any other features which you believe would be useful", 71 respondents provided a response. Of those, several specific features were suggested, and insights provided. Multiple respondents wanted a higher quality and humanlike voice for a robot, some suggested that the voice should be able to be tailored to the patient's preferences and be able to handle multiple languages with automated translation built in. From an implementation perspective, one subject suggested that to help a SAR-augmented telerehab system to succeed, a 24-hour tech support team could be available. Several therapists highlighted that having a method for cleaning robots that interact with patients is important. Multiple subjects had a vision for improving the screen, which included making it larger and clearer and allowing the operator to show other videos, demonstrations of activities, instructions, replays of the patient's activity with video overlays, and closed captioning of speech. The exemplar robot is limited in that it does not have legs, several respondents pointed towards a desire to have legs that move like the arms and, if possible, even an articulating trunk. A subject also suggested that more advanced hands with fingers would be useful for their practice. Several subjects highlighted how a demonstration system with cameras could be used for automated assessments, suggesting that the robot could demonstrate movements for range of motion assessments and exercises and that it could even be used when a therapist is not available to monitor patient adherence and report back to the therapist. Multiple therapists wanted the opportunity to measure biomarkers which are non-obvious by video, such as pulse, blood pressure, body temperature, hand strength, muscle tone, arm strength, and leg strength. Therapists picked up on the difficulty of deploying systems remotely that can guarantee safety, handle cluttered environments, open doors, etc. One therapist suggested adding "silly add on features (like a Mr. Potato Head)" as well as building variety into prompts and exercise programs to maintain engagement. Another suggested adding scent and other relaxation tools to the robot to be able to tailor the robot for various patient ages and dementia. A few therapists also provided their concerns with robots being built that could displace them and decrease the quality of care for patients, highlighting limitations of robots today that cannot catch a patient, cannot move a patient, cannot fix patient hardware, and need local support. Several therapists also highlighted perceived limitations that are important to them, focusing on the operator being able to speak to patients (which the exemplar system can do, but was not clearly demonstrated in the video).

The results for the questions prompted by "In this section we ask for some final thoughts on robotics in healthcare" are shown in fig. 3. Eighty-seven percent of the therapists agreed that more study needs to be done on how robots affect function. Only 2% felt that failing to use robots for treatment would be unethical. When asked "What other feelings do you have towards robots", 93 therapists provided a response. Responses ranged from negative to positive.

Fig. 2. Summary of responses by therapists to “What features do you believe are useful in a system to make telerehabilitation work well?”. Each bar shows the responses with the count of responses for each option reflected by the length of each color. The responses are centered about “Neutral” with the percent of respondents who selected “Neutral” for each question shown. The percentage on the left indicates the percent of the respondents answering “Extremely Useless” or “Somewhat Useless”. The percent on the right indicates the percent of respondents answering “Extremely Useful” or “Somewhat Useful”. Abbreviations with full questions are listed in table I.

Fig. 3. Summary of responses to questions prompted by “In this section we ask for some final thoughts on robotics in healthcare”.

Multiple therapists focused on the need to use robots only with the right patient population and in the right situations. They highlighted a lack of existing knowledge on when, where, and with whom robots are helpful. Some thought that deployments when other avenues of care are not available, such as during a pandemic, makes sense. Multiple therapists were concerned that social robots might be detrimental to the development of patients with behavior and communication disorders by distracting them, changing social dynamics, and getting in the way of parent-child bonding for young children. Others specifically highlighted these populations as ideal for working with robots. Multiple respondents were

concerned that older adults would resist new technology, but others posited that as the field advances, resistance to technology will decrease. It was highlighted that for patients where safety is a concern, due to, for example, a fall risk or pain, that a robot cannot guarantee patient safety today and that more generally if patients are poorly positioned, injury could result. Some felt that rural locations are a good place to use robots, but others highlighted that robots can be too expensive for rural clinics. In general, multiple therapists expressed concerns about costs, especially when considering the challenges with deploying fleets and maintaining support and steep learning curves. Similarly, a therapist was con-

cerned about reimbursement and time spent on robot setup. Some were also concerned about technical barriers, like poor internet access in their clinics. Multiple saw use cases in stretching and strengthening as part of an established plan of care but one was also concerned about robots not providing the correct amount of challenge to patients, causing them to become dependent on the robots.

Multiple therapists highlighted the importance of in-person interaction with patients. That trust in the therapist and patient-therapist relationship is what enables effective therapy, comforting a patient leads to better outcomes. Therapists in person can pick up subtle cues, and manual manipulation is required for both assessment and treatment, especially in inpatient settings. They noted that they must adapt to changing situations during therapy, which is challenging for robots. No therapists suggested that robots should replace therapists and multiple who were positive towards using robots emphasized that they should be used to augment the care that patients get from their therapists.

There were multiple therapists who were open to the idea of robots but need to see more data to show that robots are beneficial for patient care and outcomes and need guidelines on when robots should be used. Even those who are positive about robots in healthcare have concerns that it will fail in practice, where reliability is necessary.

C. Response Themes

The result of Bartlett's test is: $\chi^2(435) = 6160, p \approx 0$, indicating a factor analysis is appropriate. The knee in the scree plot is between 5 and 7 factors. Kaiser's Rule and Horn's parallel analysis both suggest that 6 factors be used. The factor analysis led to the construction of 6 themes:

- **“Features for Social Robots and Advanced Telepresence”**: Captures features that could be used in social robots, advanced telepresence systems, and/or SAR-augmented telepresence systems, including driving autonomously (feat-mobileAuto), driving under a clinician's control (feat-mobileManual), having arms and a face (feat-socialArms, feat-socialFace), social interactions with patients autonomously (feat-socialAuto), playing games (feat-socialGame), performing autonomous assessments (feat-assessmentAuto), and having a web interface (feat-webInterface).
- **“Positive Feelings”**: Captures positive feelings toward robots (feel-positive), the inverse of negative feelings toward robots (−feel-negative), belief that robots will improve patient independence (feel-patientIndependence), allow caretakers to focus on higher level tasks (feel-careFocus), improve clinician well-being (feel-clinicianWellbeing), are like other medical devices (feel-medDev), and are accurate (feel-robotAccurate). Also captures the unrelated and opposing variables: should act autonomously (feel-automatic) and should act under clinician control (feel-clinicianControl).
- **“Telepresence Features”**: Captures features needed to make any telepresence system high quality: a clear

Fig. 4. The results across the entire data set for each of the themes using the coarse model. Results are shown as a violin plot (estimating the kernel density function), with a box plot and the mean as a diamond. The theme score corresponds to the scale of the questions (-2: very negative, -1: negative, 0: neutral, 1: positive, 2: very positive).

screen (feat-clearScreen) and high-quality video (feat-hqVideo).

- **“Societal Concerns”**: Captures concerns about possible negative impacts on society from using robots: belief that the use of robots is in general bad for society (feel-societyBad), is unethical (feel-unethical), will damage people's ability to interact with other people (feel-damageInteraction), will cause clinicians to lose their jobs (feel-lostJobs), and that not using robots would be unethical (feel-notreatUnethical, although logically opposed, the loading is positive).
- **“Feasibility Concerns”**: Captures concerns about the feasibility of deploying rehab robots: feelings that robots are too expensive (feel-expensive), take too long to set up (feel-setupTime), will be rejected by patients (feel-patientReject), and fail too often (feel-robotFailure).
- **“Research & Regulation”**: Captures feelings that robots need to be studied further (feel-study), we need more laws governing the use of robotics (feel-laws).

The mean of the questions assigned to each theme were taken, yielding the scores seen in fig. 4. Across the sample, this model has the following Cronbach's alpha values: “Features for Social Robots and Advanced Telepresence” 0.92, “Positive Feelings” 0.84, “Telepresence Features” 0.97, “Societal Concerns” 0.72, “Feasibility Concerns” 0.67, “Research & Regulation” 0.51.

1) *Theme Values*: By observation of the plots (fig. 4) it appears that the scores for the themes “Telepresence Features” and “Research & Regulations” are non-normal, necessitating non-parametric tools. The “Features for Social Robots and Advanced Telepresence” theme scores are skewed, but the large sample size allows for the use of parametric tools. The remaining themes appear normal and have large sample sizes. A two-sided t-test was performed on the responses to those themes to determine if the mean differs from zero. For the two non-normally distributed themes, a two-sided Wilcoxon Signed Rank test was performed to determine if the median differs from zero. The tests for the themes “Features for

Social Robots and Advanced Telepresence”, “Telepresence Features”, “Societal Concerns”, “Feasibility Concerns”, and “Research & Regulation” all yield p-values of approximately zero, so we conclude that the population for each of those themes is not centered at zero. The test for the “Positive Feelings” theme produces a p-value of 0.5, so we are unable to conclude that its true mean is different than zero. The confidence intervals show that “Feasibility Concerns” (CI: 0.52 to 0.63), “Features for Social Robots and Advanced Telepresence” (CI: 0.45 to 0.63), “Telepresence Features” (CI: 1.50 to 1.75) and “Research & Regulation” (CI: 0.75 to 1.00) are all above neutral (zero) and “Societal Concerns” (CI: -0.51 to -0.38) is below neutral (zero).

IV. DISCUSSION

A. Feelings Towards Robots in Healthcare

A first takeaway is that therapists are not a monolithic group, there are multiple questions with nearly equal numbers of therapists agreeing and disagreeing. The most positive response within the general feelings towards robots is that therapists believe we need to study robots more. Combined with answers of feeling generally positive toward robots and insights from the open-ended questions, there is an indication that therapists are open to the development of robots in healthcare. However, evidence of efficacy is needed, with an emphasis on when, where, and with whom systems are appropriate. Therapists also responded that they would like more laws surrounding robots in healthcare, there is an opportunity for the robotics community to engage in policymaking to help lay the foundation to improve the lives of both providers and patients.

However, several responses center on perceived deficiencies of robots: that they are too expensive, patients will reject them, robots fail too often, and robots take too long to setup. These sentiments agree with prior reports demonstrating robots to clinicians [22] and mirror results from Winkle et al., where therapists expressed concerns over the costs associated with robots and whether SARs could be tailored enough to meet specific patients’ needs [23]. However, practical experience has shown that patients do accept robots [14], [15], [17]. Adopting recommendations from the therapists to make customizable systems with a variety of interaction pathways may address some of these challenges, but risks increasing complexity of systems, which must be managed. Building systems which are designed to be robust, for example by using teleoperation where autonomy is not yet reliable, will, as noted in the open-ended responses, eventually allow both patients and clinicians to become more comfortable working with robots and allow them to be viewed as just another medical device, which responses here show they are not.

Of particular concern is that therapists do not think that robots will improve clinician well-being. Prior technology pushes (for example, electronic health records) have overloaded clinicians. It is important that, as we develop robots, we focus not just on the patient, but also on the clinician.

Therapists do not appear to want robots that act on their own and they do want ones that they control, which presents

comparable results to a study performed in 2008 with healthcare professionals who responded positively to using robots for healthcare only when controlled by a clinician [25]. For robots to be used they need to be accepted by clinicians and clinicians expect to be in control.

B. Features for Telerehabilitation

There were more positive than negative ratings for all the features proposed in the survey. The therapists wanted high quality video and a clear screen, above any of the social robot focused features which were proposed. The open-ended questions proposed additional ways in which the screen could be enhanced for patients, with additional information in overlays and other videos.

The therapists also seemed excited about automated assessment, which could remove the need to scrub back and forth over the video captured during the interactions to assess patients. We believe that this is an area in which roboticists and computer vision experts could make a strong contribution. Although the therapists ranked a system which can autonomously drive itself lower than one which is manually driven, only 18% felt that autonomous mobility would be somewhat or extremely useless, compared to 69% who disagreed or strongly disagreed when asked “I want robots that act on their own”. This highlights the importance of discovering which tasks should be offloaded from clinicians.

More than half the therapists felt that robots with a face and arms would be useful. Many in the open-ended questions wanted legs added along with a higher quality voice.

C. Themes

The factor analysis allows the description of the latent themes underlying the questions. All themes except “Research & regulation” have good internal consistency. Based on the confidence intervals of the centers of the themes, we can say that a large group of therapists from across the United States, with a wide range of backgrounds expressed (fig. 4):

- 1) Some concern towards the feasibility of using robots in healthcare, due to cost, ease of setup, rejection by patients, and robot failures.
- 2) That features which would be used in SAR-augmented telepresence for rehab are somewhat useful.
- 3) Clear feelings that more research should be done on robots in healthcare and that more regulations and guidance are needed on their use.
- 4) Slight lack of concern about societal implications of using robots in healthcare.
- 5) That fundamental telepresence features of high-quality video with a high-quality screen are very important for telerehab to work well.

Statistically significant positive feelings (or lack thereof) towards robots in healthcare were not found.

D. LIMITATIONS

The responses to individual questions on social robot + telepresence features are positive. However, it is important to acknowledge the potential bias introduced by asking feature

questions like these after introducing a system with many of the features (Flo) which the survey designers built. Another limitation is that the questions asking about general feelings toward robots in rehabilitation were asked after Flo was presented and the features questions were asked. Although the questions about feelings toward robots explicitly ask to rate on robots generally, it is possible that some respondents answered about Flo. The internal consistency for the Research and Regulation theme is low. This is in part due to the small number of items included in each, which reduces the score [29]. This study only evaluated responses by therapists in the United States, future work should include determining the sentiments of other stakeholders. Additionally, the survey was distributed by convenience using digital methods, which could bias the sample group. Despite these limitations, this study, with a large number of respondents, provides useful insight to the field on the thoughts and feelings of therapists towards robots in rehabilitation and features to focus on for telerehab, examining in particular features for SAR-augmented telerehab.

V. CONCLUSION

In this paper, we have described the opportunity for social robots to augment telerehabilitation, briefly described an example SAR-augmented telerehab system, and explored the results of a large study to understand how therapists view robots, telehealth, and the specific use of social robots for telerehabilitation. We have evaluated the raw data as well as the summarized themes to uncover concerns among therapists over the feasibility of using robots for rehabilitation and over a lack of regulations and data on robots. While we cannot say that therapists have positive feelings towards robots, we have shown that they do not have negative feelings towards them. Finally, we have explored specific features that therapists want in telerehab robots: clear screens, high quality video, control, and features expected in SAR-augmented telerehab.

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