RESEARCH AND DEVELOPMENT NEEDS AND THE ROLE OF REHABILITATION ENGINEERING IN COMBINING THERAPY AND SOCIAL ROBOT APPLICATIONS

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ABSTRACT

In recent years, rehabilitation robotics has gained much attention. Assistive and therapeutic robots with social features are currently being used in a variety of rehabilitation settings. However, these social robots have severe technological and clinical limitations that impede their implementation as successful therapeutic interventions. This paper discusses the needs, challenges, and potential solutions. These include the need for an interdisciplinary approach and relevance to rehabilitation engineering.

BACKGROUND

Rehabilitation robotics is an emerging field of research with substantial potential to assist therapists and clients in a variety of settings and populations, including geriatrics, pediatrics, cognitive and social rehabilitation, and special education. Rehabilitation robot applications fall into two main categories: 1) Assistive Robots (AR), and Therapeutic Robots (TR) [1]. These robots may or may not have a social interaction feature. For example, MIT-MANUS is an assistive robot with no social interaction, while PARO is a socially assistive robot that interacts with, but does not "assist" the user. The social capabilities enable a robot to respond to the user, either verbally, or physically. In general, social robots tend to increase the motivation of the user to accomplish the therapeutic activity, or use the robot for assistance [2]. Some social robots are humanoid, and some look like animals or pets. The form factor serves to enhance the social experience [3], however, there is no evidence to the best of our knowledge that one form elicits better responses from the users than the other.

Figure 1: PARO robot [5]

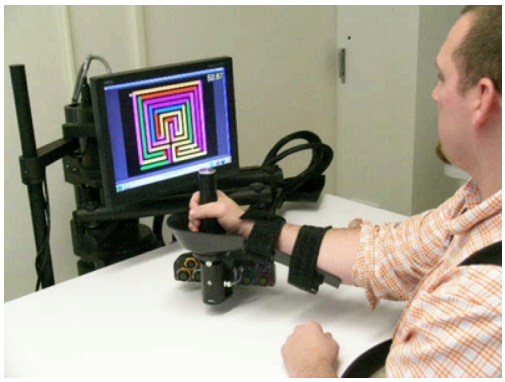

Figure 2: MIT-MANUS robot [6]

Both social and non-social assistive and therapeutic robots have been found to improve physical and mental health for a variety of clients with various diagnoses. These robots mainly assist with rehabilitation from stroke, Parkinson's Disease, traumatic brain injury, spinal cord injury, cerebral palsy, and autism [1, 5]. However, it seems that with some social robots, such as NAO (a humanoid robot, shown in figure 3), social features and activities are the goal of human-robot interaction (HRI), as opposed to being used as means for increasing motivation for therapeutic and assistive activities.

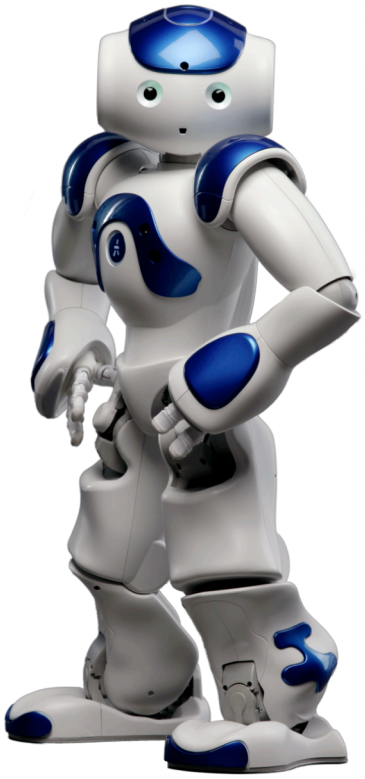

Figure 3: NAO robot [7]

Despite the numerous studies conducted on rehabilitation robotics, the effectiveness and efficacy studies on robotics in rehabilitation, especially regarding the objective outcome measures, are limited [4, 6]. This paper is aimed at defining and describing the development needs and requirements to increase the effectiveness of Social Therapeutic Robots (STRs), both from a technological and a clinical standpoint.

RESEARCH AND DEVELOPMENT NEEDS

STRs are currently facing many challenges that impede their effective use. These challenges and needs can be classified into two categories of technological and clinical. The challenges respective to each of these categories form the basis for the premise that rehabilitation engineering has an important role.

Technological Challenges

1) **Lack of awareness of the participants' situation and background:** Regardless of how advanced the STR is socially, so far, no robot, that we have found, is able to understand the feelings of a participant in a therapy session, and base the exercises and activities on the participants needs and goals. This severely limits the ability of STRs to assist therapists. Especially considering the trend towards client-based therapy, this limitation of social robots is probably their most challenging technological deficit, leading to an inability to increase one of the key aspects of therapeutic activities, motivation, through responsiveness to the client's current mood and behavior.

   Therapists need to personalize key elements of therapy, such as: providing knowledge of the situation to the client, modifying exercise type, providing feedback and positive reinforcement when necessary, considering client's goals and interests along with that of the therapy's, and prompts or reminders when necessary [2]. All these key elements are presently absent from even the most advanced STRs.

2) **Physical-sensory limitations of STRs**: If the goal of therapy is to restore function, the STR must be able to perform that function flawlessly in order to achieve the goal of therapy with the client. However, current STRs are unable to utilize their sensors to achieve the same perception of the events as the client. Physical restraints are also another technological limitation for STRs, especially humanoid types. For example, the NAO robot is unable to perform shoulder abduction of more than 90 degrees, due to the mechanical limitations of its "glenohumeral joint". This would simply keep this robot from accomplishing a successful shoulder range of motion therapy session.

3) **First social, then therapeutic:** Currently, all of the robots that are

being used in geriatric or pediatric settings are designed with "social" features in mind first, and then "therapeutic". There are robots that can say hello or hold one's hand and follow one around the room, or respond by blinking if one pets their head, but they have trouble balancing themselves if they are nudged. This becomes very important when the therapeutic aspect of the robot requires it to interact with clients physically. There seems to be a need for robots that are social, but are also built with therapeutic goals in mind.

4) **Complexity of programming:** Therapists are going to be both the experts on the topic of STRs and the potential users of them [2]. Programming social robots to prepare them for their activities or to assist the therapist must become standard and main-stream. Current programming software that are used to program social robots for therapeutic activities are either too complicated for therapists (low-level), or are too limited due to simplicity (high-level). Standardization of a universal language that is easy to understand, for programming STRs, would assist therapists with less technical background.

5) **The "umbilical cord" between the robot and a computer:** Social robots are either completely autonomous, or are connected to a computer. The completely autonomous robots have limited function and programmability, and maintenance of the connection between the connected robots and the computer is often an overlooked challenge. If a robot is going to be unable to perform without connection to a computer, technological means for establishment of secure and robust connection should be a priority.

Clinical needs:

1) **Exploration:** definition and introduction of novel and useful therapeutic activities that can be carried out by STRs within the constraints of their technological limitations is a key step in optimizing the STRs' application in therapy.

2) **Development of Activities:** Intervention protocols need to be developed to integrate the STR into therapy. Development of potential interventions also relies on the technical capabilities of STRs.

3) **Validation of Outcomes:** To measure the effectiveness and efficacy of STRs, and to provide feedback for technical and design improvements, as well as intervention protocols, the outcomes of interventions using STRs need to be measured and validated. Development of best clinical practices relies on this key step.

Methods

ROLE OF REHABILITATION ENGINEERING

Engineers are well-equipped to address the technical challenges stated above. Therapists, on the other end of the spectrum, have the knowledge of the therapeutic and clinical needs. However, lack of a common ground between the two professions, impedes the abilities of both sides to address the needs of rehabilitation. One possible approach to address the challenges discussed earlier, as well as the ones yet undiscovered, is a multidisciplinary approach. Currently, programs such as Health Sciences, Occupational Science and Technology, Biomedical Engineering (Biomechanical and Bioelectrical), and Rehabilitation Engineering, provide a great opportunity for experts and students from both sides, engineering and healthcare, to collaborate on resolving such challenges.

Government and federally funded agencies such as the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR), National Science Foundation (NSF), and National Institute of Health (NIH), are currently supporting multidisciplinary efforts through programs such as Knowledge/Technology Transfer (KT/TT), I-Corps, and Translational research programs or grants.

CONCLUSION

Social Therapeutic Robots have substantial potentials to revolutionize therapeutic activity's administration. However, in order to facilitate wider acceptance and application of STRs in therapeutic activities, technical and clinical needs must be addressed. The field of Rehabilitation Engineering has the potential to bring together engineers and therapists to address these impairing challenges. Resolving these needs could result in wider acceptance of STRs, which in turn improves the outcomes of therapy by increasing the motivation of clients, and by reducing the need for therapists to engage in high-intensity and repetitive therapeutic activities.

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