NEXT GENERATION OF ASSISTIVE SOCIAL ROBOTICS: THERAPEUTIC APPLICATIONS

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ABSTRACT

Socially assistive robotics (SAR) is a growing area of research with the potential to provide several benefits to a wide variety of contexts. Although the current SAR applications yielded several beneficial outcomes, the utilization of SAR in the current practice is still limited to the social capabilities of the robots, and mainly focus on socialization goals. However, there are several therapeutic potentials for the use of SAR in the context of physical, emotional, and cognitive rehabilitation, especially considering the recent development of humanoid robotics and sensor technologies. The aim of this paper is to discuss some potential futuristic therapeutic applications for the utilization of SAR as a therapist assistant. These robots have the potential to provide automated coaching, task-specific feedback, encouragement and motivation of functional and therapeutic exercises. The paper also provides a therapeutic application example of SAR in Stroke rehabilitation, and discusses some the futuristic needs in both research and developments.

INTRODUCTION

Social robots, or as the literature refer to it, socially assistive robotics (SAR) is a growing area of research with the potential to provide several benefits to a wide variety of contexts including elder care, education, rehabilitation, and for people with social and cognitive disorders. Assistive Robotics (AR) is the general family that encompasses several robotic applications, and include rehabilitative robotics, wheelchair robots and other mobility aids, companion robots, manipulator arms for the physically disabled, and educational robots (Matarić, Tapus, Winstein, & Eriksson, 2009). SAR in another member that can be added to this family, and is defined as the intersection of AR and Socially Interactive Robots (SIR), which are machines that interact primarily through social interaction (Feil-Seifer & Mataric, 2005).

The main emphasis and the large and growing body of SAR therapeutic applications have been limited and revolving around utilizing the social capabilities of the robots. The first efforts to utilize SAR have focused on robotic pets or companions (Matarić et al., 2009). In this context, the companion robots were designed to fulfill some of the roles of pets, while excluding the burden of animal care, in an attempt to reduce stress and depression and improve physiological and psychological health in elderly patients. Such companions include PARO, Sony AIBO, and the Huggable from MIT (Tapus, Mataric, & Scassellati, 2007).

SAR use with individuals in the autism spectrum disorder (ASD) has also been investigated. A number of studies reported that social robots generate a high degree of motivation and engagement in children with autism, including those who are unlikely or unwilling to interact socially with therapists (Michaud & Clavet, 2001).

The potential use of SAR in the context of physical rehabilitation has been demonstrated by Matarić et al. (2009). They presented a hands-off therapist robot that can assist, encourage, monitor, and interact with patients (Figure 1). The use of this robot resulted in an increased compliance with rehabilitation exercises in subjects' home context.

Although these applications yielded several beneficial outcomes, the utilization of SAR in the current practice is still limited to the social capabilities of the robots, and mainly focus on socialization goals. However, there are several therapeutic potentials for the use of SAR in the context of physical, emotional, and cognitive rehabilitation, especially considering the recent development of humanoid robotics and sensor technologies. This paper provides some potential therapeutic applications for the utilization of SAR as a therapist assistant to provide automated coaching, and task-specific feedback, motivation and encouragement of therapeutic exercises. It provides a therapeutic application example of SAR in Stroke rehabilitation, and discusses the future needs in research and developments.

Figure 1: A social robot and participants performing free movement exercises (Matarić et al., 2009)

SAR AS THERAPY ASSISTANTS

The recent development of humanoid SAR presents a promising opportunity for utilizing these robots for delivering task-specific therapeutic exercises in several settings, such as clinics, schools, elder-care facilities, and more importantly in clients' homes. The human-like movement capabilities of these robots make it possible for therapists to program a robot to execute a certain sequence of movements and to coach a therapeutic session, without the need for the therapist to be present. Such sessions can include simple exercise routine for the elderly, where the robot executes each movement and asks the participant to follow and repeat the movement it is making, or it can include an active range of motion exercise by asking a stroke survivor to move his/her arm to the same range performed by the robot for example.

The following are different activity types, that exemplify the type of assistance a humanoid SAR, NAO®, a non-contact social robot, produced by SoftBank Robotics, can provide as broader therapeutic interventions/goals (future applications) (Ardehali, Obiedat, & Smith, 2018).

- Simple Playful Activities: an example for this type would be playing a simple game such as hitting a beach ball attached to a wire back and forth.
- Simple Task Repetition Evaluation and Active Monitoring (STREAM): activities such as basic hand movement from designated point A to point B and back fall under this category.
- "NAO Says…": Activities in this type are similar to that of the game "Simon Says", in which participants are required to mirror the gestures the activity coach makes, only if they are made after saying "Simon Says", or in this case "NAO says".
- "Follow me": NAO asks the participant to follow a movement it is making. For example drawing an arch in the air with one hand while holding NAO's hand (Figure 2).
- "Hand me that!": An example of this activity would be the subject asking for an object to be handed to him/her by NAO. For example, "NAO hand me a napkin". NAO follows the order and assists the participant.

<u>Task-Specific Feedback</u>

Feedback can be classified into two categories, intrinsic or extrinsic feedback. Intrinsic feedback is the sensory perceptual information from internal sensory processes received by the individual such as visual, auditory, proprioceptive and tactile information. In the other hand, extrinsic refers to feedback from an external source such as verbal feedback provided from a therapist (Molier, Van Asseldonk, Hermens, & Jannink, 2010). There are two categories of external feedback, knowledge of results (KR) and knowledge of performance (KP). KR has been defined as externally presented information regarding the performance outcome or achieving the goal of the performance. KP is externally presented information about the characteristics of the movement itself that led to the outcome (Molier et al., 2010). Typically, extrinsic feedback is given in addition to intrinsic feedback. However, intrinsic feedback is often disturbed in several conditions, such as stroke and TBI, due to the damage in the brain. Thus, providing extrinsic feedback in therapy is even more important, as the existing research findings suggest that the provision of feedback may enhance motor learning and functional performance (Popovic, Kostic, Rodic, & Konstantinovic, 2014).

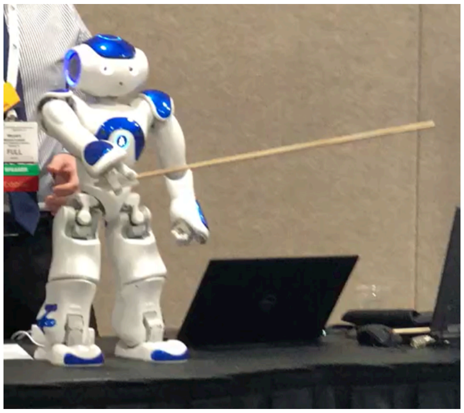

Figure 2: NAO® robot performing ROM exercises

In conventional rehabilitation, the therapist is the one responsible for providing extrinsic feedback during therapy. Advances in sensors technology made it possible to measure several aspects of movement's characteristics and performance. Therefore, several sensors can be implemented in a robot which can enhance the capabilities of providing various objective extrinsic feedback about the performance of a client in rehabilitation. SARs can be equipped with several sensors and might be the best alternative to substitute the therapist role in providing consistent, human-like, detailed and individualized extrinsic feedback in rehabilitation programs. Additionally, these sensors can monitor, measure, and report the user performance to the therapist.

Encouragement and Motivation

Another critical factor that need to be considered is the psychosocial aspect of the rehabilitation process. Since participation is a prerequisite to increased treatment, motivation is a key factor in sustained participation which will lead to greater recovery during the rehabilitation process. Motivation is an integral factor in rehabilitation and is frequently considered as a determinant of rehabilitation outcome (Colombo et al., 2007). In occupational therapy (OT) interventions, the therapist plays an essential role in providing individualize and goal-directed motivation and encouragement for the client to complete a therapeutic task. Generally, this factor has not been emphasized in the available robotic rehabilitation systems. SAR are capable of providing the needed encouragement and motivation, especially if the robot is equipped with the right sensors, movement analysis can be used to guide the delivery of task-specific encouragement and motivation in real-time.

SAR in Stroke Rehabilitation

One of the most devastating disabilities after stroke is the loss of upper extremity motor function, leading survivors to suffer from an increased dependency in their activities of daily living and a general decrease in their overall quality of life (Langhorne, Bernhardt, & Kwakkel, 2011). Therefore, the restoration of arm and hand function to improve survivors' independency is crucial.

The recovery process after stroke is complex and requires a combination of spontaneous and learning-dependent processes. There is a compelling evidence that high-dose intensive training and repetitive practice of specific functional tasks are important for recovery after stroke (Langhorne et al., 2011). However, the delivery of such rehabilitation requires supervision of trained professionals which makes stroke rehabilitation a labor-intensive process, and more importantly, cannot meet the growing needs for rehabilitation activities supervision, both in and especially outside clinical setting. The resulting need of stroke rehabilitation created a niche for the development and testing of new technologies (tools) capable of filling the gap created by the lack of availability of human care. Thus, an increased effort has been devoted to the development and testing of post-stroke robot-assisted therapy. As a result, several effective systems have been developed, that mainly focused on using hands-on physical contact. However, these systems raised several safety concerns (Matarić et al., 2009). Additionally, these systems are very expensive, and lack portability and generally used only in clinical setting (Matarić et al., 2009). Moreover, not all effective rehabilitation therapy requires the use physical contact between the therapist and the patient. Conventional OT has been proven as an effective intervention for stroke rehabilitation for centuries. Several OT interventions do not require physical contact between the therapist and the survivors. Constraint-induced movement therapy is another prominent example on the effectiveness of non-contact therapy for stroke rehabilitation.

Humanoid SAR are excellent candidates to provide therapists with the needed assistant in this field. In order to use SAR to provide coaching for repetitive, task-specific, and high-intensity interactive treatment of the impaired limb, it needs to perform movements/tasks in front of the client, or be able to describe the movement/task. They also need to be able to measure patients' compliance and monitor motor progress objectively, measure changes in movement kinematics and forces, and provide task-specific feedback and motivation.

FUTURE RESEARCH AND DEVELOPMENTS

Several key factors need to be considered and implemented to the next generation of humanoid SAR to advance the its therapeutic application. In order for SAR to be effective in coaching a therapeutic session, the robots should not have any mechanical limitation in terms of executing human-like movements, including normal ROM specifically in upper extremities. For example, NAO® is one of the most humanoid robots available in the market at this point. This robot has several limitations in its ROM as it is unable to perform shoulder abduction for more than 90 degrees, and lacks the supination/pronation movements.

Another key factor that need to be considered is the ability of the robot to recognize human movements, to provide autonomous task-specific feedback and motivation, and monitor and report clients' progress objectively. This can be achieved by implementing some additional sensors in the robot. For example, the Kinect™ V2 can measure the changes in ROM and was validated for general movement analysis of shoulder, elbow, and hand (Otte et al., 2016). The integration of such system in the robot will provide it with this capability of performing basic movement analysis.

Maximizing the productivity in the delivery of rehabilitation without sacrificing the quality of care patients receive can be achieved by developing evidence-based therapy, or by increasing the productivity of the therapists which can be achieved by providing therapists with appropriate tools. Thus, developing the next generation of humanoid SAR is essential, and the efficacy of using SAR as a tool for delivering different therapeutic applications need to be fully studied. There are several therapeutic applications that can be delivered by the available humanoid SAR at this point. However, an inter-disciplinary effort between therapists and rehabilitation engineers is needed for implementing and testing the effectiveness of these applications.

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