Emerging Roles for Social Robots in Rehabilitation: Current Directions

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Insights from social and cognitive neuroscience should inform the design of socially assistive robots for neurorehabilitation as novel roles emerge for them in human-human interactions.

CCS Concepts: • **Human-centered computing** → *Interaction design; Interaction design theory, concepts and paradigms*;

Additional Key Words and Phrases: Human-robot interaction, socially assistive robotics, neurorehabilitation

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1 INTRODUCTION

Roboticians are developing Socially Assistive Robots (SARs) to address care gaps in rehabilitation, such as for stroke survivors, older individuals, individuals with dementia, individuals with motor impairments and disabilities, and children with autism spectrum disorders [1–3]. SARs are unique in their social capabilities and are able to provide assistance through social interactions [4]. SARs are thus poised to become promising tools in rehabilitation, in which factors that largely depend on social interaction, such as engagement and motivation, play a central role in recovery.

Neuroscience has long informed the design and use of robots for *physical* assistance in rehabilitation of motor impairments. These robots have been widely used across rehabilitation contexts, assisting in practicing upper- or lower-limb movements and motor relearning, as well as in training proprioception, cognitive functions, and attention [5]. The integration of robots into physical rehabilitation has proven promising, with studies showing that patients who receive combined robot-mediated therapy and physical rehabilitation are more likely to achieve therapy goals than those who receive traditional therapy alone [5].

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Fig. 1. An illustration of the elements from social and cognitive neuroscience that should underlie the design of socially assistive robots for rehabilitation in order to generate trust and motivate users to engage with the robot. The emerging roles of social robots as both probes and as modifiers of human-human behavior are also illustrated here.

Just as neuroscience has guided engineers and roboticists in developing innovative *physical* features for robots used in neurorehabilitation, it can – and should – also guide the design of the *social features* of SARs as they are integrated into rehabilitation research and practice. For roboticists, the challenge remains to create social robots that can perceive the user’s needs, feelings, and intentions, and adapt to a broad range of cognitive, physical, and communication abilities. The successful implementation of SARs in rehabilitation will depend both on technological improvements *and* on the acceptance of SARs as members in a social environment [1]. We posit that SARs used in rehabilitation should exhibit (1) trustworthiness, (2) empathy, (3) behavioral adaptation, and (4) cultural sensitivity (Figure 1). We highlight how social neuroscience has provided novel insights into the design of these features as well as how these features are, in turn, beginning to influence human-human interactions.

2 TRUSTWORTHINESS

Trust is an essential feature of the patient-clinician relationship in rehabilitation and has become a central topic of discussion for the implementation of SARs in this context [1, 7]. Since it is imperative that both the patient and the clinician trust the SAR to perform rehabilitative tasks, our psychological understanding of how humans trust one another can be useful in determining how to design trustworthy robots. Consequently, in order to measure trust in human-robot interactions during rehabilitation, researchers have borrowed paradigms, simulations, and questionnaires from social and cognitive neuroscience.

In recent years, research on this topic has uncovered what factors contribute to users’ trust in robotic agents during interactions [8]. Now, researchers are using developmental robotics – i.e., the design of behavioral and cognitive capabilities in artificial agents, inspired by developmental psychology – to enable a robot to estimate the trustworthiness of the person it interacts with [9].

Roboticians have also introduced the concept of “inverse trust,” whereby a robot can estimate its own trustworthiness during an interaction with a user and subsequently modify its behavior in an attempt to increase the user’s trust and accomplish shared goals [8]. These new features will be especially useful in accomplishing joint tasks in rehabilitation, in which treatment outcome and compliance with SAR-suggested rehabilitative exercises could be influenced by the degree to which a user trusts the SAR.

2.1 Empathy

Like trust, empathy is recognized as a core element of the patient-clinician relationship and is associated with improved treatment outcomes [10, 11]. Here, too, roboticians have turned to principles of cognitive neuroscience to inform the design of empathetic robots. One example can be seen in the use of SARs in pain management: Trost et al. were able to develop and use an empathic SAR to effectively decrease pain and fear associated with peripheral IV placement in children [11].

2.2 Behavioral Adaptation

An additional challenge for roboticians developing SARs for use in rehabilitation is the design of behavioral adaptations, in which the SAR can adapt its behavior by inferring the specific assistive services needed to support a person in different contexts [12] and vary this behavior for different user populations [4]. Recent approaches to meeting this challenge are based in cognitive-neuroscience: roboticians developed algorithms based on cognitive architectures to allow SARs to reason at different levels of abstraction, understand specific health-related needs, and decide how to act in order to perform personalized assistive tasks [12].

2.3 Cultural Sensitivity

In addition to designing SARs for rehabilitation with diverse patient populations, clinicians and roboticians must develop culturally competent robots that can assist people according to the culture of the individual they are supporting. That is exactly what the international, multidisciplinary project “CARESSES” aims to do [13]. Research in this domain has investigated how cultural psychologists and robotics designers conceptualize culturally sensitive robots and suggests how future work can produce more generalizability across cultures, which will be relevant to the use of SARs in rehabilitation globally.

3 EMERGING ROLES FOR SOCIAL ROBOTS

While neuroscience has informed robotic design, robots also generate valuable insight into the function of nervous systems, specifically in the areas of perception, locomotion, and sensorimotor coordination. Robots can serve as “interactive probes” [14] to assess the sensory and motor mechanisms underlying human-human interaction. As SARs are endowed with more human-like capabilities, they will become more useful as probes of human behavior.

Furthermore, as human-robot interactions become ubiquitous, researchers have considered how human-robot interactions may actually be influencing human-human interactions. Early studies using robot therapy with older residents of care facilities demonstrated that interactions with the robotic seal Paro encouraged residents to communicate more with each other and strengthen their social ties [15]. More recent studies have shown a similar effect; the introduction of artificial agents has been shown to influence human social behavior by improving human discussion in a collaborative task [16] and decreasing agitation in people with dementia [17], and improve interpersonal evaluation [18]. The continued use of SARs will undoubtedly reshape rehabilitation as we know it, and it will become increasingly important to consider the ways in which the incorporation of SARs will alter the social dynamics of the patient-clinician relationship in rehabilitative care.

Future research will continue to benefit from the intersection of neuroscience and robotics to equip SARs with social and intelligent features, allowing the robots to reason, understand, empathize, trust, and ultimately perform tasks for specific health-related needs [14] in a way that is user specific rather than a “one-size-fits-all” approach. Collaboration between social neuroscientists and roboticists will be crucial to enhance the implementation – and ultimately effectiveness – of SARs in rehab.

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