In-Situ Design and Development of a Socially Assistive Robot for Paediatric Rehabilitation

Felip Martí Carrillo[1,2]; Jo Butchart[3,4]; Sarah Knight[4,3]; Adam Scheinberg[3,4]; Lisa Wise[1]; Leon Sterling[1]; Chris McCarthy[1]
{fmarti, cdmccarthy}@swin.edu.au

[1]Swinburne University of Technology, Melbourne, Australia
[2]Data61 – CSIRO, Melbourne, Australia
[3]Royal Children's Hospital, Melbourne, Australia
[4]Murdoch Childrens Research Institute, Melbourne, Australia

ABSTRACT

We present the in-situ design and development of a general purpose social robot (NAO) as a therapeutic aid for paediatric rehabilitation. We describe our two-phase design approach, emphasising frequent patient/parent/therapist engagement and outline roles and requirements for our SAR prototype derived from this process. Our SAR prototype has now been deployed in the rehabilitation program of 9 patients with cerebral palsy, across 14 sessions where evaluation and iterative development is ongoing.

Keywords

In-situ Design; Socially Assistive Robots; Rehabilitation

1. INTRODUCTION

Rehabilitation outcomes rely critically on patients adhering to a prescribed set of rehabilitation exercises. When those patients are children, maintaining compliance, focus and motivation during tiring, uncomfortable and repetitive exercise programs presents a significant challenge for therapists and carers. Socially Assistive Robots (SARs) provide assistance through social interaction and engagement [2], and are increasingly being considered to support both rehabilitation [3, 4] and a range of health care delivery needs including exercise promotion with older adults [1], and post-stroke rehabilitation [5].

In partnership with a busy paediatric rehabilitation clinic, we are developing and evaluating software to adapt the humanoid robot NAO (Figure 1) as a therapeutic aid for paediatric rehabilitation. Unlike previous work, we are focussed specifically on the needs of clinical deployment, in particular to lead therapy sessions for children with cerebral palsy undergoing intensive post-operative rehabilitation. We aim to increase exercise compliance and maintain emotional well-being, particularly when therapists are not in attendance.

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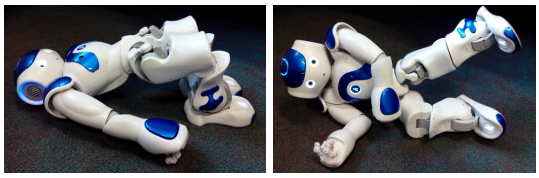

Figure 1: Two examples of rehabilitation exercises

2. DESIGN APPROACH

We are currently engaged in a two-phase in-situ design process. Through this we aim to deliver a clinic-ready system for formal clinical trials.

Phase 1 (Exploration) has two key objectives: determination of SAR roles and requirements through rapid prototyping and mock-ups (via *Wizard-of-Oz* control); and establishing the legitimacy and acceptance of the technology with stakeholders. Activities are conducted predominantly on-site, over the course of frequent unstructured visits. Data is gathered through investigator observation and unstructured consultation with patients/parents, therapists and doctors.

Phase 2 (Formative Evaluation and Development) focusses on deployment and iterative development of the SAR. A stand-alone minimum viable SAR prototype (based on Phase 1 findings) is developed and deployed in patient sessions. Robot performance data is gathered during sessions, and patient/therapist/parent perceptions of trust, usefulness and therapeutic benefits are gathered via semi-structured interviews at the completion of each session.

3. DESIGN OUTCOMES

The present study has completed Phase 1 and is currently undertaking Phase 2 in preparation for formal clinical trials.

3.1 Phase 1

During Phase 1 the SAR engaged with over 30 individual patients during weekly visits to the rehabilitation clinic over an 8 month period. Engagement was initially opportunistic, unstructured and focussed predominantly on general interactions with children, parents and therapists in the clinic's waiting area. Robot interactions explored simple dialogue, exercise/movement demonstrations and dancing.

After 2 months, emphasis shifted to specific therapeutic uses upon request from a therapist - most commonly

to demonstrate specific exercises, and to co-participate in sessions with patients. Effective use-cases for the SAR were gradually established, leading to more focussed development of key roles. Observations of patient performance indicated improved compliance with therapists' instructions when the robot co-participated, and increased motivation to complete exercise sets whe the robot was present. These observations lead to the determination of 3 key roles:

Demonstrator: NAO demonstrates exercises at the beginning of each set, and provides verbal instructions.

Motivator: NAO provides verbal encouragement at the beginning, during, and at the end of each prescribed exercise. Entertainment through music, dancing and joke telling are also offered upon completion of exercise sets.

Companion: NAO is a co-participant during the session, joining in and providing empathetic statements to acknowledge the child's progress.

3.2 Phase 2

An initial base prototype system is now undergoing iterative development and evaluation as part of Phase 2. The robot leads patients through rehabilitation sessions of up to 30 minutes. Exercise demonstrations are provided in front of the patient, before then inviting the patient to join the robot in completing a set together. Therapist-provided verbal instructions are delivered before and during each exercise. Entertainment through joke telling and dancing provide enticements to the patient to complete each task.

Presently, the prototype system has been tested in 14 sessions with 9 different patients not involved in Phase 1 (7 female, 2 male between 3 and 16 years old), over a 3 month period. Five therapists have delivered care with the assistance of the robot over this period. In these sessions the robot operates autonomously, without Wizard-of-Oz control or technician intervention.

3.3 Requirements for Clinical Deployment

Both phases of design and development have identified the following key requirements for the use of NAO as a clinic-ready therapeutic aid for rehabilitation:

1. *Configurability:* Therapists must be able to pre-load rehabilitation exercises, number of repetitions, etc.
2. *Stability:* To minimise failure, demonstration exercises must utilise joint poses and movements that remain within conservatively defined operating limits.
3. *Adaptability:* To ensure the therapeutic assistance is aligned with the patient's presenting needs, the SAR should adapt to patient mood and progress, allowing in-session adjustment of activity settings (eg, repetitions, speed and sequence order).
4. *Interaction:* Basic interaction with the SAR should be supported for both carer and patient throughout the session. This will support *Adaptability, Responsiveness* and maintain patient engagement.
5. *Integration:* The SAR must be easily setup, portable and operable by carers without specialised training.
6. *Responsiveness:* The SAR should recognise the patient's mood and progress, and respond appropriately.
7. *Stand-alone:* The SAR should be operable without technicians, *Wizard-of-Oz* or additional hardware.
8. *Robustness and Endurance:* The system should operate continuously. Unforeseen interruptions such as falls, or unintended/incorrect user interactions should be recoverable from.

3.4 SAR Evaluation

Data collection and analysis of SAR performance is ongoing, assessing fulfillment of system requirements and patient/parent/therapist perceptions of the system's usefulness. The current system is close to realising most listed requirements at an acceptable level for trials, with further development required to boost interaction and responsiveness. These are high priority areas of future work and regarded as crucial for maintaining patient engagement over the extended intensive rehabilitation program intended for clinical trials. Early analysis of survey and interview responses indicate therapists generally agree that the SAR is useful, in particular for increasing patient motivation to comply with prescribed exercises, and for exercise demonstration - particularly when they are not present. Full analysis of collected Phase 2 data will be the focus of future publications.

3.5 Design Process Evaluation

A focus on frequent (weekly) hospital visits and in-situ development over an 18 month period has been the key to the high volume of patient interactions driving the SAR development. A key component of this has been the direct inclusion of therapists in the co-design of the system, in which therapists directly program specific exercises themselves through manual manipulation of robot limbs. While time-costs were initially high, this co-design approach has been observed to increase familiarity, trust and ownership of the resulting SAR prototype, thereby boosting acceptance.

4. ACKNOWLEDGMENTS

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