1:15–2:30 P.M.

Concurrent Sessions 2

Independence D

Interactivity with Automation

PAPER SESSION

Towards the Development of Semi-Supervised Rehabilitation Systems for the Home

With the aging of the US population, there is an increasing need for effective and accessible rehabilitation services for debilitating illnesses and injury such as stroke [2]. Effective rehabilitation requires intense training and the ability to adapt the training program based on the progress of the patient and the judgment of the therapist [3]. Adaptive home based rehabilitation is emerging as a key avenue for improving health and wellness outcomes with the potential for reducing costs [1, 4]. While there are a number of challenges to scaling adaptive rehabilitation in the home (e.g. cost, motivation, adherence etc.), in this paper we describe our approach in aspiring to replicate the therapist presence and experience in the home. Here we describe our methodology in working within the nascent design space of evidence based adaptive healthcare. Evidence based adaptive healthcare has quantitative data at its core and can benefit greatly from advances in computation. Our focus is on designing adaptive home based rehabilitation systems for stroke survivors that can automatically track and assess complex human performance;

in our case adaptive rehabilitation training. Creating such systems requires a multidimensional approach integrating technical, medical, social, design, and human computer interaction knowledge.

We present our progress in co-designing an interactive system for upper extremity stroke rehabilitation in the home. Our interdisciplinary team of designers, engineers, computer scientists, doctors, patients, and therapists are iteratively designing, prototyping, and refining an experimental table top system for the home. While our goal is to ultimately create a robust system for lightly supervised use, we are first concerned with accomplishing key human-centered design activities that are essential for our development: i) analyzing and structuring performance for computational assessment; ii) collecting and assessing video data; iii) defining a movement performance rating rubric; and iv) rating the videos by experts. Findings from these activities will inform our algorithmic approach for the ultimate automated assessment of human performance in the home.

Analyzing and structuring performance for computational assessment: Working with the rehabilitation experts on our team, we developed a standardized set of exercises for upper extremity rehabilitation of stroke survivors. The set of exercises need to scale in complexity and map well to activities of daily living. To achieve the generalizability of a limited set of exercises mapping to many activities of daily living, they used an implicit segmentation of the exercises into types of segments that held true across all the exercises. For example, they looked at the characteristics of initiation, progression, or termination of movement (IPT) across all different types of exercises.

These exercises are realized using a custom-designed collection of modular objects that can be combined and configured in a variety of ways. We developed a prototype interactive system (see Fig. 2) for performing and capturing the exercises which comprises the objects, a custom mat, and a tablet interface delivering the exercise protocol (e.g. instruction videos indicating what objects to use and how to perform the exercise).

Collecting and assessing video data: We collected video recordings of nine stroke survivors attempting the 12 exercises while using the system in exploratory (non-therapeutic) study sessions at a rehabilitation hospital in the south east of the United States. Two women and seven men participated in the collection process, two with moderate impairment and seven with mild to moderate impairment. Each participant session was video captured through a two-camera setup (one sagittal for torso and shoulder capture, and one tabletop camera for capturing the wrist and fingers).

Defining a movement performance rating rubric: As there is a lack of consensus among therapists regarding the standardized, quantitative assessment of movement quality components and the influence of such components on overall functional ability [Levin], there is a need to create a consistent, quantifiable performance assessment rubric that is usable and appropriate for both human and computational agents. Our team prepared a simple web application for viewing and rating the collected video data from the nine participants. A team of four therapists spend two days viewing the data and collaborated to define a standardized movement segmentation approach for the exercises observed. Our team then built on this to create a more robust online system for rating movement performance based on this rubric.

Rating the videos by experts: Our online system supported 12 participating therapists in viewing and rating the video data (stored on encrypted USB drives shipped to the therapists) according to the rubric developed by our therapist team (see Fig 1.). Figure 3 depicts the movement segmented interface, where therapists can rate and rationalize their assessments.

We are currently assessing the inter-rater reliability of this work and analyzing the findings from an online survey review and a two-day workshop with the assessment team. Findings from these results can help improve the assessment rubric, the rating interface, and the overall performance of the therapists in understanding the nuances of their own therapeutic approach and their ability to make standardized evidence-based decisions.

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