Chapter 41
Activities and Evaluations for Technology-Based Upper Extremity Rehabilitation

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ABSTRACT

Recent advances in projection and sensing have resulted in an increased adoption of virtual reality, video games, and interactive interfaces to improve patient compliance with rehabilitation programs. In this chapter, we describe the application of multi-touch tabletop surfaces to physical and occupational rehabilitation programs that are focused on the upper extremities. First, we detail the participatory design processes undertaken with local physical and occupational therapists to design and integrate a 'patient-friendly' multi-touch tabletop system in their workplace. We then explore the design considerations that informed the development of a suite of sixteen multi-touch interactive activities. The design considerations highlighted the need for customization and flexibility in the software, as well as the importance of supporting a variety of activity types. We then detail the laboratory-based methods that were used to evaluate the efficacy of the activity interventions as well as our deployment of the system in a local rehabilitation hospital. Our evaluation, which employed both qualitative and quantitative components (i.e., the Intrinsic Motivation Inventory, semi-structured interviews, kinetics and kinematics recorded from motion trackers and an electromyogram recorder), determined that it is the design of activities, rather than the utilization of technology itself, that impacts the success of technology-assisted rehabilitation. The chapter concludes with a discussion of the implications of our system and its deployment.

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1. INTRODUCTION

More than 10% of Canadians are afflicted with impairments that influence their ability to perform everyday activities (CANSIM, 2009). These disabilities stem from a variety of causes, including aging, disease, stroke, trauma, or congenital health issues. Most commonly, patients have decreased motor functionality, memory problems, and an inability to focus on, or attend to, stimuli, leaving many unable to live independently or perform daily activities such as cooking, eating, or dressing. In traditional rehabilitation programs, occupational and physical therapists work closely with patients to perform exercises to regain or maintain physical (e.g., range of motion, coordination, balance, muscle strength, and muscle endurance) and cognitive (e.g., attention, short-term memory, visual-spatial abilities, and problem-solving skills) function to improve the patient's quality of life.

Current upper extremity rehabilitation activities, such as drawing images on paper, tracing letters in the air, or reaching for imaginary targets, require patients to perform repetitive movements that focus on increasing range of motion, coordination, muscle strength, and muscle endurance.

Most traditional motor and cognitive rehabilitation activities are monotonous and unexciting, providing sub-optimal patient engagement and immersion. It is very common for these activities to cause patients to exert only moderate amounts of effort or neglect them completely. In addition, therapists are limited in how they can manipulate the activities with respect to intensity and difficulty, and the subjective nature of patient performance makes the monitoring and evaluation of patient progress very difficult.

A new area of Human-Computer Interaction, *technology-assisted rehabilitation*, has begun to focus on the role that technology can play in improving patient abilities. It has been widely recognized that patient motivation and patient compliance with rehabilitation exercises are critical problems in physical therapy programs (Chang et al., 2011; Flynn & Lange, 2010; Gupta & O'Malley, 2006; Mumford et al., 2008; Rizzo & Kim, 2005; Saposnik et al., 2010). One approach to encourage compliance and increase motivation has been to use video games, as it is believed that patients can become as highly engaged with their therapy exercises as video game enthusiasts are with their games (Rizzo & Kim, 2005). For this reason, various technologies such as the Microsoft Kinect (Chang et al., 2011; Delbressine et al., 2012), PlayStation EyeToy (Rand et al., 2008), and Nintendo Wii (Saposnik et al., 2010) have become pervasive in therapy programs (Flynn and Lange, 2010). Preliminary research into integrating gaming, virtual reality, and haptics into rehabilitation programs has illustrated that technology-assisted rehabilitation can decrease the length of a patient's rehabilitation program, increase a patient's range of motion, muscle strength, and coordination, and provide rehabilitation opportunities in out-patient or rural settings (Gupta & O'Malley, 2006; Mumford et al., 2008).

Over the last decade, interactive surfaces and multi-touch tabletops have become very popular, partially due to their decreased cost. Interactive tabletops have several advantages (Hutchins et al., 1985) that make them excellent candidates for the rehabilitation process. By their very nature, multi-touch tabletops support natural and direct interaction (Wigdor and Wixon, 2011), that is, the user touches and manipulates an object or target directly instead of using a proxy device such as a mouse, keyboard, or joystick for interaction. As patients with cognitive disabilities often have trouble creating a mapping between a proxy object and target, this direct interaction provides an important advantage. Interactive tabletops also provide a large interaction space, which is to exercise gross motor function and encourage lateral upper-body movement (Annett et al., 2009; Mumford et al., 2008). Such interaction is not possible on small hand-held devices or tablets. Multi-touch tabletops have the potential to greatly enhance patient