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A Robotic Home Telehealth Platform System for Treatment Adherence, Social Assistance and Companionship – an Overview

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Abstract—**Well-known difficulties of making patients adhere to assigned treatments have made engineers and clinicians look towards technology for possible solutions. Recent studies have found that cell phone-based text messaging can help drive positive changes in patients' disease management and preventive health behavior. Furthermore, work in the area of assistive robotics indicates benefits for patients although robotic solutions tend to become expensive. However, continued improvement in sensor, computer and wireless technologies combined with decreases in cost is paving the way for development of affordable robotic systems that can help improve patient care and potentially add value to the healthcare system. This paper provides a high-level design overview of SKOTEE, the Sister Kenny hOme ThErapy systEm, an inexpensive robotic platform system designed to provide adherence support for home exercise programs, taking medication, appointment reminders and clinician communication. SKOTEE will also offer companionship as well as entertainment and social networking opportunities to the patient in their home. A video of the system is presented at the conference.**

I. Introduction

PEOPLE with chronic health conditions commonly have difficulty adhering to medical and rehabilitative recommendations. Individuals who self-administer prescribed medication may take less than half the recommended dose [1]. People may miss or come late to appointments, not initiate (or partially implement) a recommended treatment, not complete behavioral recommendations or homework (e.g., diet or exercise changes), make adjustments in medication regimens (e.g., taking too many or too few pills or doing so at incorrect times), or prematurely discontinue treatment [2]. Low adherence for rehabilitation patients has been linked to greater numbers of medical emergencies, increased number and strength of prescriptions, worsening of disability and prognosis, greater likelihood of complications, and compromised recovery from injury [3]. A review of 39 empirical studies [4] concluded that "current methods of improving medical adherence for chronic health problems are mostly complex, labor-intensive, and not predictably effective". Subsequent reviews have lead to similar conclusions [1, 5].

Conceptions of patient-professional partnerships around self-determination and self-management are replacing earlier paternalistic conceptions of non-compliance as irrational and deviant individual behavior [6]. Accordingly, adherence is increasingly recognized as a multi-factorial construct [7]. The Ecological Model of Adherence for Rehabilitation [7] conceptualizes adherence as an enterprise in which an individual makes self-determined health-related decisions and then learns and implements health behavior intentions. This model suggests that adherence is optimized as patients receive professional support to establish health-related implementation intentions and use technology to help them enact and monitor those intentions in their everyday lives.

People who form implementation intentions (planning when, where, and how they will perform goal-directed behaviors) are more likely to enact new behaviors that have not been habitualized [8]. Implementation intentions have been used to promote exercise, healthy eating, and cancer-related self-examinations [8]. Similarly, client controlled feedback, feedback in which the schedule of information about performance is controlled by the client, supports self-determined health behavior change [9]. Clients identify when they wish to get information about their performance, rather than receiving information on a schedule.

Mobile technologies (cell-phones, wireless computers) have the potential to support self-determined health behavior change at a number of junctures in the adherence process (cf. [10]). Three key features of mobile technologies are particularly important: automated functions (e.g., notification reminders [meds]), decision-support (analysis of self-test data and feedback), and anytime/anywhere communication and intervention capability (emergency consultation) [11]. Results of a recent review suggest that interventions delivered through cell phones via short-message service (SMS) have a positive impact on health

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behavior change [12]. Positive behavior changes were observed in 13 of the 14 studies. Ten of these studies involved disease management (asthma, hypertension, diabetes) and four involved preventive health behaviors (smoking cessation, physical activity). The potential of technology-supported adherence may be further actualized when used in combination with implementation intentions. Prestwich et al. [13] demonstrated the effectiveness of pairing implementation intentions with reminder cues delivered via SMS in advancing exercise behavior.

Robot assisted therapy for home-based rehabilitation may be a cost-effective means to deliver healthcare due to an increasing need to deliver health care outside the clinic [14]. Robotic systems have usually been designed to provide some form of physical assistance to the patient but recent initiatives include socially assistive robotics [15] and evidence suggesting that a robotic dog works almost as well a real dog to decrease loneliness and help elderly residents to form attachments [16]. Home-based robotic system could also be combined with various wearable sensors for health monitoring through what has been termed a Wireless Body Area Network [17, 18].

In the current paper we provide a desing overview of SKOTEE, the Sister Kenny hOme ThErapy systEm, an inexpensive robotic platform system designed to provide adherence support for home exercise programs, taking medication, appointment reminders and clinician communication. SKOTEE will also offer companionship as well as entertainment and social networking opportunities to the patient. A rendering of SKOTEE is shown in Fig. 1.

Fig. 1. Conceptual rendering of the SKOTEE home robot system. The current prototype is based on the iRobot Create® development platform.

II. Methods

The first prototype of SKOTEE has been built through a collaborative Engineering Design project with six Mechatronics Engineering students of the Royal Institute of Technology in Stockholm, Sweden and four Mechanical Engineering students of the University of Minnesota. Researchers at the Sister Kenny Research Center (SKRC) in Minneapolis have originated the project and they function as advisors to the students. A graduate student of the Royal Institute of Technology on site at the Sister Kenny Research Center in Minneapolis coordinates the two engineering teams and acts as their "Lead Engineer". A video of the prototype system is presented at the Conference.

A. Hardware Platform

The student teams have developed a module-based system, consisting of a main unit and one exercise module. The main unit is the moving robot that would be part of the system for all categories of patients. The initial exercise module provides a concept for arm exercises. There are several advantages of a module-based system including flexibility across different categories of patients and simplicity to add new modules to improve on the system. The main unit of the initial proof-of concept system is based on the Create® development platform by iRobot (Bedford, MA, USA). Future implementations will use the more robust ERA-MOBI platform by Videre Design (Menlo Park, CA, USA) (Fig. 2).

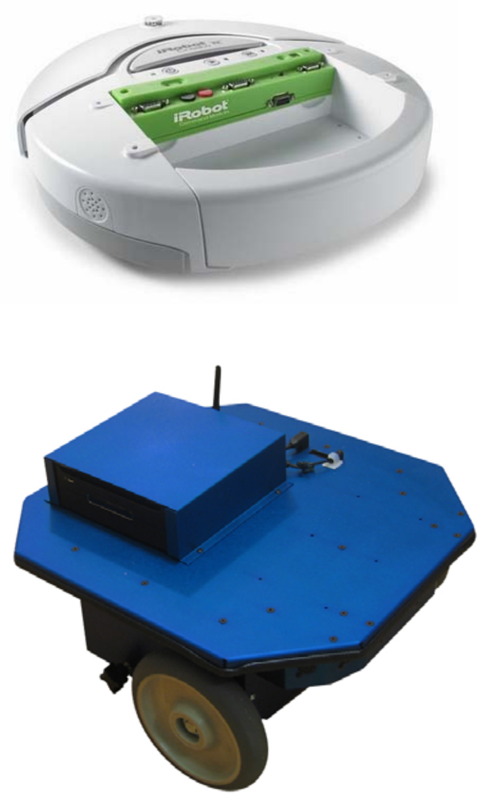

Fig. 2. The iRobot Create® development platform (Top) and the ERA-MOBI by Videre Design (Bottom).

B. Design Specifications

The SKOTEE system must be intuitive to use and simple to learn and maintain for both patients and clinicians. It must be safe to both operate and be around for the patient. The robot should be easy to clean and maintain. Off-the-shelf components should be used whenever possible to ensure low system cost. The initial prototype of the system is based on the following main specifications that were derived by the SKRC research team. This list is not complete.

The robot has been designed to:

- Move around and navigate on its own in a home environment and negotiate common obstacles (carpet edges, thresholds, door openings etc.) and avoid walls, stairs and furniture.
- Find its way between stationary objects like a charging station and mobile objects like the patient.
- Recharge itself and not run out of batteries. A charging station should therefore be the place, where the robot automatically returns when batteries are running low.
- Be fully functional while recharging.
- Remind the patient about various events and appointments and provide step-by-step instructions for certain actions.
- Help motivate the patient to adhere to an exercise protocol through clear instructions that may include text, audio and/or visual cues.
- Allow the clinician to log on to the robot, customize the exercise program, create reminders and monitor patient progress and to deliver a message to the patient.
- Record the patient's voice and capture video sequences of the patient while he/she is exercising and share this information with the therapist.
- Allow the clinician to engage with the patient through a video communication system with pan, tilt and zoom functionality.
- Provide entertainment and companionship for the patient unrelated to therapy. This could include audio books, music, games and/or television.
- Wirelessly interface with exercise modules for real-time monitoring of patient performance.
- Allow the patient to communicate with the robot in an easy, technology-transparent and robust manner. The interface may include a touch screen, remote control and voice recognition.
- Keep a safe distance from the patient and not be in the way and warn the patient if this distance cannot be kept.
- Have a "go to sleep"-function so it can leave the patient alone if requested.

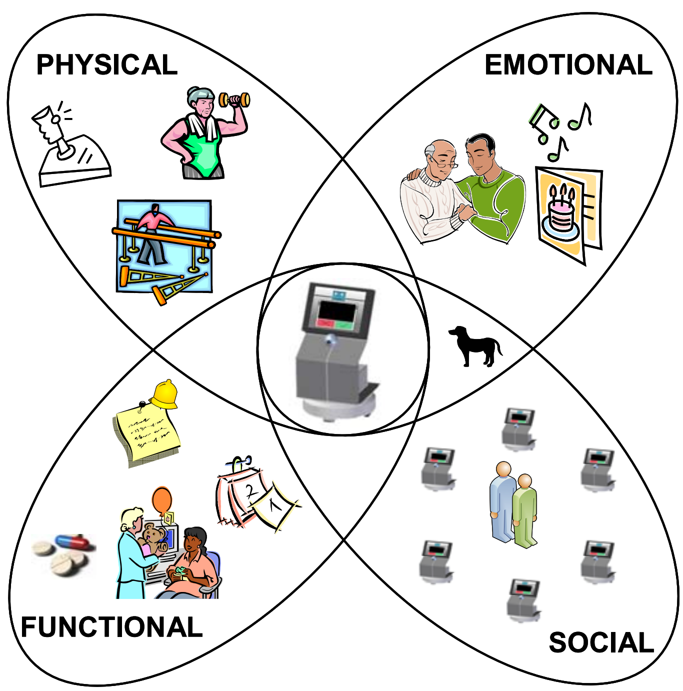

Fig. 3. The patient-centric aspect of the SKOTEE system illustrates the intent to provide support across several dimensions of quality of life that may relate to treatment adherence.

III. Results and Discussion

We have provided a brief overview of the design of a robotic system, SKOTEE that is intended to provide patient specific support across several dimensions of quality of life. Fig. 3 illustrates the "patient-centric" features of the system related to physical, emotional, functional and social aspects of a patient's life that the system may provide. These features should encourage the development of a bond and a sense of companionship between the patient and SKOTEE. A recent study has shown that social attachment can develop between a robot and elderly individuals [16]. To enhance adherence to treatment through the use of technology it appears a social attachment to the system in use would be beneficial. Such a bond between a robot and an individual may be strengthened further by designing a system that can actually identify the patient through voice, image or other recognition system.

Fig. 3 illustrates the hospital/clinic-centric aspect of the system. A number of deployed SKOTEE devices would wirelessly communicate with a central server were all data would be stored and analyzed. Clinicians can easily query the database and generate reports either for individual patients or for subgroups of patients. One clinician could easily monitor and advise several patients simultaneously who may be located in very different geographical locations.

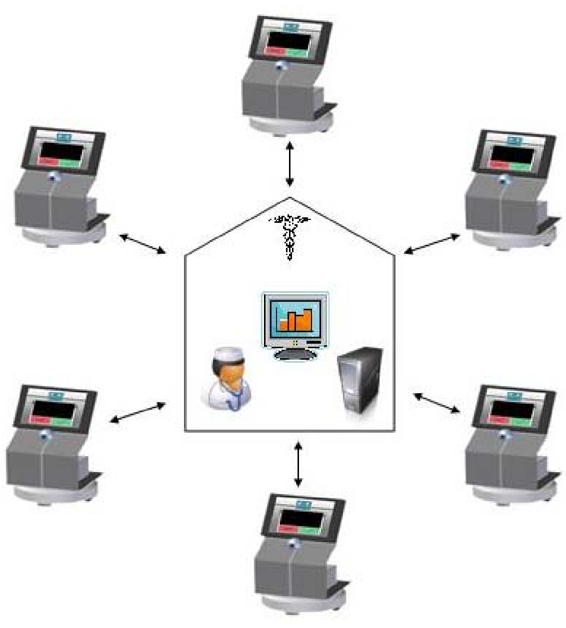

Fig. 4. Hospital-centric view of the SKOTEE robotic system deployed across a number of patients' homes. Each robot would upload data to a central server where clinicians would have access to data on an individual or population basis.

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