InnoMotion: A Web-based Rehabilitation System Helping Patients Recover and Gain Self-Awareness of Their Body Away from the Clinic

Abstract
In the physical therapy or occupational therapy rehabilitation process, patients often perform routine exercises away from the clinic. Being away from the eyes of a professional can undermine a patient’s confidence and impede recovery if the patient is not performing the exercises correctly. We propose InnoMotion, a system designed to aid in recovery away from the clinic. We conducted research to determine what aspects of the rehabilitation process are crucial to successful recovery. We designed a web-based system that works in tandem with motion-sensing technology (e.g., Leap Motion) to allow patients to perform rehabilitation exercises in their home, while collecting performance data. This data is used to guide the patient through a successful recovery.

Author Keywords
Physical Therapy; Occupational Therapy; Motion-Sensing Technology; Rehabilitation; Body Data Tracking; Gamification; Social Networks

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.
Introduction
There are a multitude of questions and uncertainties a physical therapy or occupational therapy rehabilitation patient has when it comes to understanding one’s body and progress in therapy. It is one thing to be able to perform rehabilitation exercises in front of and under the guidance of one’s clinician or therapist, but often circumstances make performing rehab exercises at home necessary (e.g., insurance/cost, transportation, severity of injury). This is a frustrating process that leaves the patient wondering whether he/she is doing the exercises correctly and is actually improving. Often a patient gets directives from the therapist at the clinic, but goes home to perform additional exercises with only instructions and images printed on sheets of paper for guidance. Adding to the uncertainty of the effectiveness of rehabilitation at home are the high costs of paying for clinical visits and the difficulty of finding ways to maintain patient motivation. Sluijs et al. (1993) argue that low patient compliance in physical therapy is correlated with feelings of helplessness, lack of positive feedback, and perceived barriers to progress [6]. To maintain patient motivation and aid in successful recovery, it is necessary to demonstrate progress, supply up-to-date positive feedback, and keep the patient invested in recovery. Furthermore, when a patient is away from the clinic, the therapist does not have knowledge of the patient’s progress.

In order to streamline the rehabilitation process for both the patient and therapist, our team designed an application that allows a patient to perform rehabilitation exercises away from the clinic, while staying in touch with a professional who monitors progress and provides feedback. Inspired by research similar to Brown et al.’s (2011) (2010) studies on upper limb and hand functions in patients with chronic disability [2][3], our application employs a calibrated motion-sensing device (e.g., Leap Motion, Kinect, Wii) to record and track data from rehabilitation exercises that a patient performs at home. The application motivates the patient to exercise through setting milestones and checklists. The motion-sensing device tracks the patient’s movement and provides feedback in real-time about the quality of the movement. The data is then sent to the therapist for review, and displayed for the patient via interactive graphics to demonstrate progress towards goals.

We developed a working web application prototype that tracks the fine gestures and movements of the hands. We employ the Leap Motion device in our prototype because it captures fine hand and finger movements. We foresee future iterations of this application supporting additional motion-sensing devices.

Related Work
With innovation in healthcare technology and treatment options, there is a growing focus on the use of gamification and technology in rehabilitation. There is a related body of work exploring the capabilities of motion-sensing technologies such as the Nintendo Wii [5] and Microsoft Kinect [4] [8] in physical therapy. So far, these devices have met with success for their low costs and ability to maintain patient motivation.

Design Research
We began our preliminary design research by exploring the rehabilitation process from the perspectives of former and current patients, occupational and physical therapists, and kinesthetic researchers. We conducted a total of 9 interviews to understand the goals, needs and characteristics of the users, to determine the limitations of the rehabilitation process, and to identify areas that could be improved with access to relevant and meaningful movement data.

In 5 patient interviews we discussed the rehabilitation process, including how goals are set, how progress is measured, and how home exercises are completed. In interviews with 2 therapists we discussed how communication with patients occurs, and what technology is used in therapy sessions. We interviewed 2 movement researchers to understand the current
trends in the field and the prevalent attitudes towards motion-sensing technologies.

We analyzed the interviews by creating an affinity wall to distill our findings into several thematic areas that informed future design decisions (see Figure 1). We found that all patients have serious concerns about the cost of rehabilitation and the limitations their insurance plans placed on them. It is very important for patients to be able to supplement their therapy sessions with exercises in the home. However, patients expressed that it is difficult to know whether they are doing their exercises correctly when they are alone. Patients often feel helpless without real-time feedback on their progress. Though the rehabilitation process can be tedious and painful, we learned that it is critical for the therapist to positively motivate the patient for a more successful recovery. Patients, therapists, and researchers all expressed a need for meaningful and accurate data that informed about the patient’s progress and performance.

Design Process
After analyzing the interview data, we constructed a conceptual map to illustrate several key features our design should contain. We also created 3 patient personas and 1 therapist persona to represent the key users of our system. A summary of our personas follows:

-Liam (primary patient persona): an ambitious, young business executive. He lives an active life and is an avid outdoorsman. Liam experienced a serious hand injury while rock climbing and is unhappy with the unexpected setback (see Figure 2).

-Tony (patient): a middle-aged basketball coach who knows that sports may lead to injury, and is very motivated to recover fully.

-Kathleen (patient): an active, social college student who is slowly healing from surgery. Kathleen is impatient and wants to recover as quickly as possible.

-Jenny (therapist): a young occupational therapist in the beginning of her career. Jenny loves helping people and working directly with patients.

Using these personas as guides, we constructed scenarios to refine the workflow and analyze how users would engage with the system. Our primary scenario guided us towards a clear understanding of how a user might perform rehabilitation exercises and share meaningful information with a therapist (see Figure 3). We created our design with our personas in mind to provide a more meaningful way for users to view and share their body data, gain self-awareness about their progress, and successfully complete rehabilitation.

We followed an iterative process of brainstorming, developing user flows, storyboarding, site-mapping, wireframing, and prototyping - including sketches, medium-fidelity and high-fidelity prototypes. We collected feedback from potential users along the way to help refine our design ideas. This feedback helped us refine our design by illustrating what worked well and what needed to be adjusted to provide the most impactful solution.

Our Solution
We propose InnoMotion, a web-based application that partners with motion-sensing technology to aid in the recovery of injuries and maintain active relationships between patients and medical professionals. The system is intended for physical rehabilitation patients and their therapists. The system provides exercises that are connected to real-world actions, in order to remain salient and engaging. A live prototype is currently available.
InnoMotion accommodates patients of various ages and technical abilities, so is designed to be intuitive, simple, and user-friendly. InnoMotion motivates patients through realistic goal-setting, positive feedback, and progress tracking. It provides real-time and aggregate performance data, and facilitates connections between patients and therapists. We describe the application through the eyes of our primary patient persona, Liam.

When Liam was at his physical therapy appointment for his injured hand, his therapist, Jenny, decided that he needed to perform exercises at home between appointments, including practicing finger movement, grasping, and wrist rotation. Liam worked with Jenny to set short-term and long-term goals. Liam received a Leap Motion device and an account to access InnoMotion at his home. Jenny assigned an exercise plan, recorded the progress she expected, and set a 2-week checkpoint.

**Rich interactions through gesture, voice and touch**

Liam has a hand injury and is unable to navigate the web with his mouse and keyboard. With the connection of the motion-sensing device, Liam is able to use gestures to interact with the application (see Figure 4). The Leap Motion sensing technology responds to gestures such as swiping, tapping, circling, and screen tapping, which allows Liam to advance through each section and fully explore the system without trouble. In this way Liam is able to access the goals and exercise plans that he discussed with Jenny. We envision several alternatives for interactions, such as voice command and touch screen.

**Data analysis for feedback and progress tracking**

Liam and Jenny rely on accurate data to gauge Liam’s performance and make decisions about treatment plans. InnoMotion provides four levels of feedback: instant feedback during an exercise, performance feedback for a completed exercise, aggregate summary feedback for an exercise over time, and a timeline visualization of progress towards the overall rehabilitation plan.

While Liam is doing the grasping exercise, he sees a real-time 3D model of his hand on the screen (see Figure 5). He sees the speed of his hand movements, and each time he completes a grasping motion, he feels satisfied when a progress bar advances. He can see in real-time that he is advancing towards the goals that he set. The exercise is accompanied by music, which motivates Liam to do the exercise to a fun rhythm. When Liam does not grasp with enough care, the system displays a prompt to tell him to correct his hand motion. Liam quickly corrects his movements. The instant feedback that Liam receives during the exercise improves Liam's motivation, awareness, and quality of movement.

When Liam completes his repetitions of the grasping exercise, a performance summary appears offering suggestions for improvement. Liam compares his actual performance to his goal. For example, he finds that his average grasping speed is 2.5 seconds, while his goal is to reach 1 second at the end of the rehabilitation process. He also sees a summary displaying his
Liam is pleased to see this progress, and remains motivated to continue the exercises. Liam also sees a visual timeline that represents his progress towards achievements and milestones. Liam can see a version of this timeline for a particular exercise, or for his overall rehabilitation plan. He compares his performance against several milestones that he set for each exercise. Liam is also able to add new goals. When he decides that he wants to bring his grasping speed down to 2.25 seconds in 1 week, he records this new goal in his timeline. According to Baker et al. (2000), both patients and therapists agree that when a physical therapy patient participates in goal-setting, recovery outcomes are improved [1]. However, in practice, patients are not always engaged in setting their own goals. Since InnoMotion allows the patient to curate goals, Liam feels a higher level of motivation to complete exercises and is more eager to engage with the system.

**Active connections between patients and therapists**

Liam’s therapist, Jenny, can see the exercise data from her patients. Through a patient management portal, Jenny has access to a dashboard showing updates and progress for all her patients. Jenny can manage her patients’ rehabilitation plans and appointments. She can access her patients’ exercise data, estimate the rehabilitation duration and adjust the plan accordingly. She can also assign new exercises from a comprehensive catalogue.

InnoMotion provides meaningful notifications to inform Jenny about Liam’s progress. When Liam has not done any exercises for 2 weeks, Jenny receives a notification, and motivates Liam by sending a personal message. Likewise, when Liam achieves one of his goals, Jenny is notified and shares in the satisfaction. The active relationship between patient and therapist is maintained even outside of the clinic (see Figure 7).

Liam is pleased with his progress and since his next appointment is not for another 2 weeks, he wants to let Jenny know that he is ready to progress to a more challenging exercise. Liam uses a messaging interface to send a request for access to the new exercise. Jenny approves the request after reviewing Liam’s performance data and noting that he is ready to move to the next level (see Figure 8). To maintain engagement and facilitate recovery, it is important for a patient to remain challenged by the exercise regimen.

Liam creates a personal profile and uses this to connect with others through the system. Liam seeks out new friends with similar hand injuries, and decides to share his performance data with one who is feeling unmotivated. Wicks et al. (2010) find that when similar patients network with each other, there is a better perceived outcome [7]. The ability to share patient data and stories facilitates engagement and helps patients understand their treatment options.

**Validation**

To evaluate our design, we gathered feedback from potential users and professors at the University of Michigan who are knowledgeable about medical technology and interactive systems. We presented our
medium-fidelity prototype to 2 patients and 1 therapist and asked participants to describe what features they liked, and what they thought could be improved. We learned that patients wanted the exercise instructions to be more easily accessible, and we learned that therapists wanted to be able to send personalized notes to their patients.

After creating a high-fidelity prototype, we conducted usability tests with 3 patients and 2 therapists (see Figure 9). We asked participants to complete tasks such as finding and completing exercises, and to describe their overall experiences and impressions of the system. Feedback was positive. One patient observed that the design made her feel good when she completed a task, and that the exercises were "fun." Therapists were enthusiastic that the system can recommend exercises based on what it knows about the patient. Furthermore, participants agreed that the design was aesthetically pleasing and easy to use.

Leap Motion does have some technical limitations, including the inability to detect hands holding objects or overlapping hand movements. However, this did not discourage potential users from believing that the application would be helpful for rehabilitation.

Conclusion
InnoMotion is a low-cost web system that works with the rehabilitation process. The system collects and presents patient performance data to track performance and measure progress towards rehabilitation goals. As motion-sensing technology becomes more refined, we imagine that InnoMotion could expand to include rehabilitation tracking for injuries on other parts of the body, such as the knee, back, or neck.

Acknowledgements
We would like to thank Dr. Mark Ackerman, Dr. Mark Newman, Dr. Pedja Klasnja and Dr. Susan Brown for their input on this project. We would also like to thank the patients and therapists who shared their experiences and gave us valuable feedback as we designed InnoMotion.

References