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Mobile, Virtual Enhancements for Rehabilitation (MOVER)

Quarterly Progress Report

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14. ABSTRACT
Injured Warfighters return home to face long-term care and recovery in addition to life adjustments. Rehabilitation services such as interventions for traumatic brain injury (TBI)- induced motor limitations, broken bones, spinal cord injuries, chronic pain, and amputation enable these Warfighters to adjust to new living constraints and conditions and, in many cases return to full health. While these services are readily available in military treatment facilities (MTFs) and veterans??? affairs medical centers (VAMCs), not all patients have the time or ability to receive prolonged inpatient rehabilitation interventions. Furthermore, lengthy inpatient treatments are costly to MTFs and VAMCs, reducing the overall number and types of services that these facilities can provide.

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INTRODUCTION AND EXECUTIVE SUMMARY

Research Goals

Injured Warfighters return home to face long-term care and recovery in addition to life adjustments. Rehabilitation services—such as interventions for traumatic brain injury (TBI)-induced motor limitations, broken bones, spinal cord injuries, chronic pain, and amputation—enable these Warfighters to adjust to new living constraints and conditions and, in many cases, return to full health. While these services are readily available in military treatment facilities (MTFs) and veterans' affairs medical centers (VAMCs), not all patients have the time or ability to receive prolonged inpatient rehabilitation interventions. Furthermore, lengthy inpatient treatments are costly to MTFs and VAMCs, reducing the overall number and types of services that these facilities can provide.

For these reasons, home-based and outpatient rehabilitation interventions hold great potential to improve the rehabilitation of our Warfighters. These rehabilitation interventions enable patients to continue with their daily lives during rehabilitation. Patients can perform professional duties; be with family; and be social with friends around the schedule of their rehabilitation practice, and all of these functions enable patients to better adjust to life changes that follow injury. Home-based and outpatient rehabilitation interventions are accessible to a wide range of patients because they lower the time and travel requirements of rehabilitation. Finally, home-based and outpatient rehabilitation interventions are less costly to MTF and VAMC service providers, enabling these facilities to provide a wider range of services to more patients.

The patient must practice therapeutic exercises regularly. The unfortunate reality of many home-based and outpatient therapies is that the patient does not regularly practice therapeutic exercises beyond visits with the therapist and, therefore, does not see significant improvement. Studies of home-based and outpatient rehabilitation interventions have identified a number of key correlates to lack of adherence: confusion about exercises; perceptions of lack of time to exercise; forgetting to exercise; perceptions of helplessness; and overall lack of motivation to exercise (Jette et al., 1998; Sluijs, Kok, & van der Zee, 1993). Conversely, patients who have less confusion, make time to exercise, remember to exercise, perceive higher self-efficacy, and report motivation to exercise adhere more regularly to rehabilitation protocols. In addition to these areas of needed patient assistance, outpatient therapists must be enabled to perform their job functions of observing the patient and directing exercises.

For these reasons, remote assistance to home-based and outpatient rehabilitation is needed to enhance the recovery of our injured Warfighters.

Description of the Technical Approach

To address these issues, we are developing mobile, virtual enhancements for rehabilitation (MOVER), a mobile, technology-enabled home-based rehabilitation intervention delivery system. MOVER features (1) a mobile application to provide education, information, and scheduling of therapeutic exercises; (2) virtual coaches to guide, mentor, and motivate patients; (3) COTS input devices and video games to increase patient motivation; and (4) a web-based therapist interface to accurately assess patient adherence and progress.

Figure 1 shows the MOVER Architecture. At the top left of the figure, the **Patient** interacts with the **MOVER Mobile Application** to perform **Exercise Scheduling** and obtain **Information and Education** about therapeutic exercises. The **Virtual Coaches** exist on the mobile application and provide interactive guidance and mentoring about the rehabilitation process and therapeutic exercises. When the scheduled time for the exercises arrives, the mobile application reminds the patient, and the patient begins an exercise session with the **MOVER Game Integration**, as shown at the bottom of the figure. The patient uses **COTS input devices**, such as the Microsoft Kinect and the Wii Balance Board, to perform therapeutic exercises that are mapped to controls of the **Video Game Console** through the **Control Mapping on Laptop,** software running on an inexpensive PC or laptop.

During interaction with the mobile application and game integration, patient **Performance** is recorded and sent securely to the **Remote Server** and **Secure Database**, at the center of the figure. The **Therapist** reviews this performance through summarized **Progress Reports** in the web-based **Therapist Interface**, as shown at the top right of the figure. The therapist then creates **Therapeutic Exercise Assignments** to describe the patient's therapeutic exercises for the next week, and these assignments are passed to the game integration for implementation the next time the patient begins exercise.

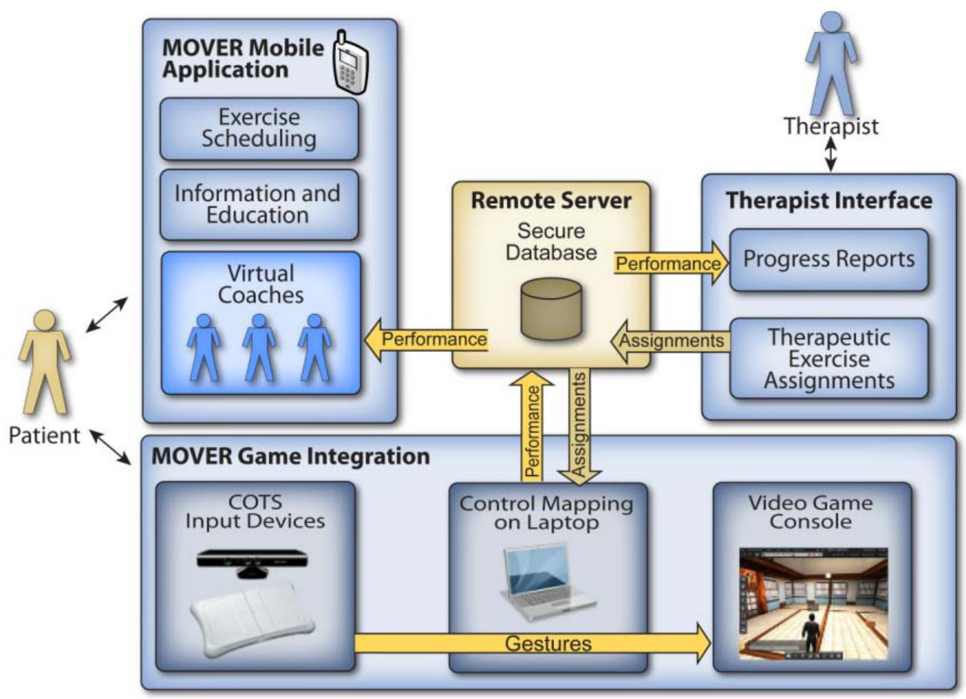
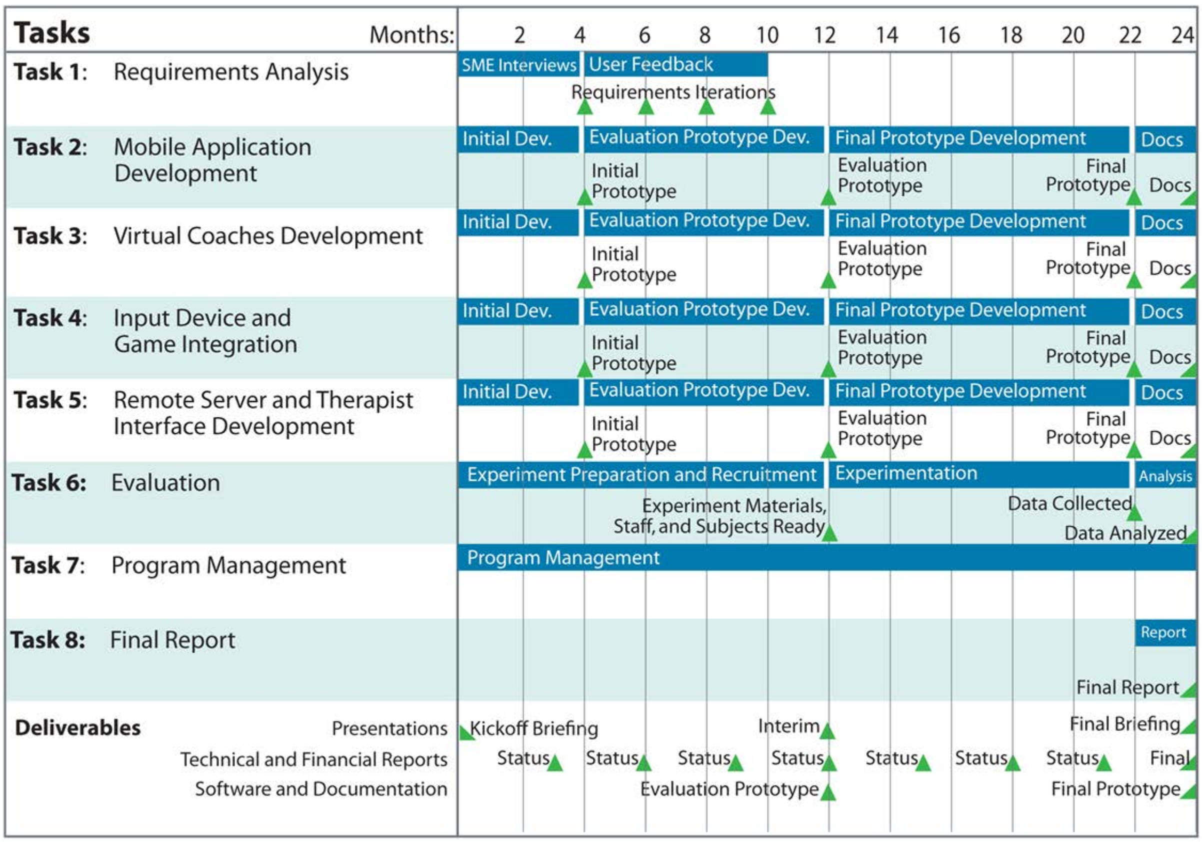


Figure 1: MOVER architecture

A typical use of MOVER in home-based rehabilitation is as follows. The patient meets with the therapist at the beginning of the week to participate in a short, one-on-one rehabilitation session. The therapist assesses the patient, prescribes a set of therapeutic exercises for the week, and works with the patient to determine a feasible exercise schedule. At the end of the session, the patient and therapist enter an exercise schedule for the week, and the therapist enters the therapeutic exercises into the therapist interface. During the week, the patient is reminded of scheduled exercises by the mobile application and motivated by the virtual coaches. The patient uses the COTS input devices to play the video games with the therapeutic movements specified by the therapist. During exercise, the virtual coaches give feedback on patient movements and form, and afterwards the virtual coaches review the patient performance. Performance information is collected and sent to the remote server. At the next session, the therapist reviews the progress reports with the patient to determine next steps for treatment.

Deliverables/Milestones Schedule



TECHNICAL PROGRESS

Progress against Planned Objectives

During this reporting period, we focused on Task 3 (Virtual Coaches Development) and Task 7 (Program Management)as presented in the Statement of Work for this effort.

Technical Accomplishments This Period

Task 3: Virtual Coaches Development

Our goal for Task 3 is to develop virtual coaches to assist home-based TBI motor impairment rehabilitation therapy through mentoring and guidance. During the current reporting period and in place of having an exercise creation tool for the therapists, we have simplified the process by hardcoding specific, commonly used balance exercises into the system and enabling the therapists to select and customize pre-identified parameters for these exercises. Figure 2 shows the exercise routine selection screen. Each exercise has a custom set of parameters. For example, Figure 3 shows the height setting for the knee lift exercise. The therapist selects the height that the patient attempts to achieve during each knee lift, and the height is visualized as a vertical percentage slider and red bar over the patient as a point of reference.

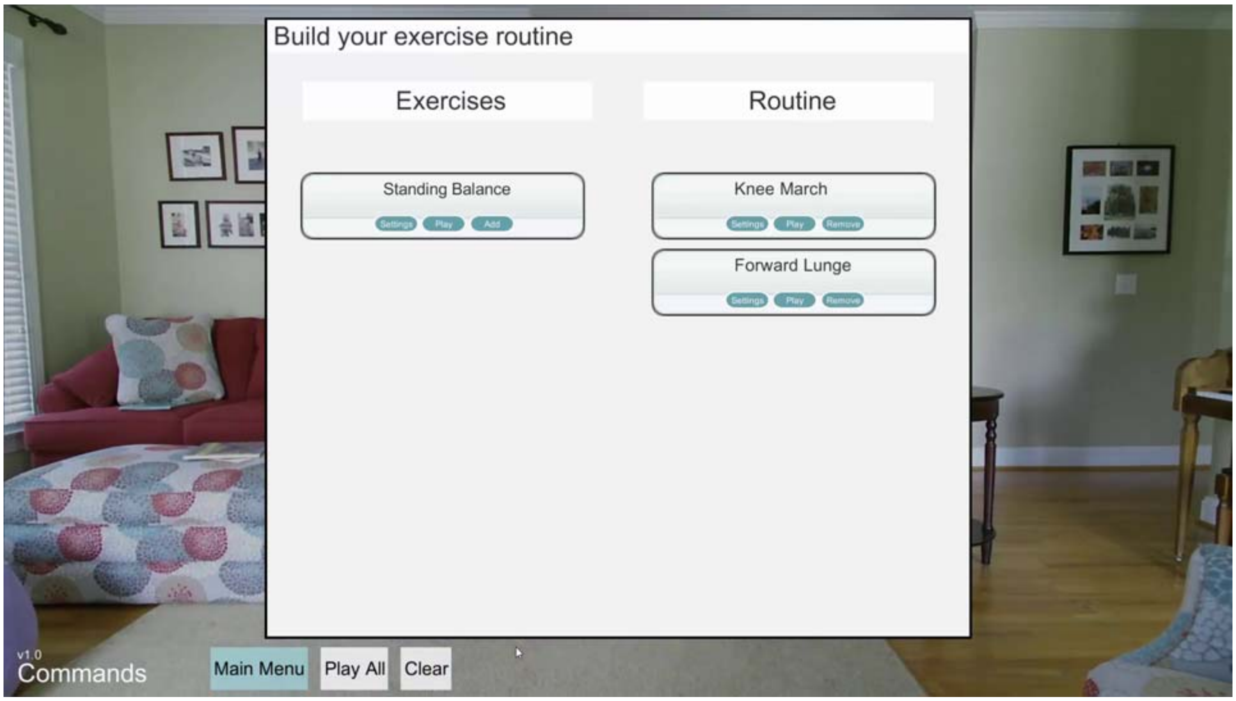


Figure 2: Exercise routine selection

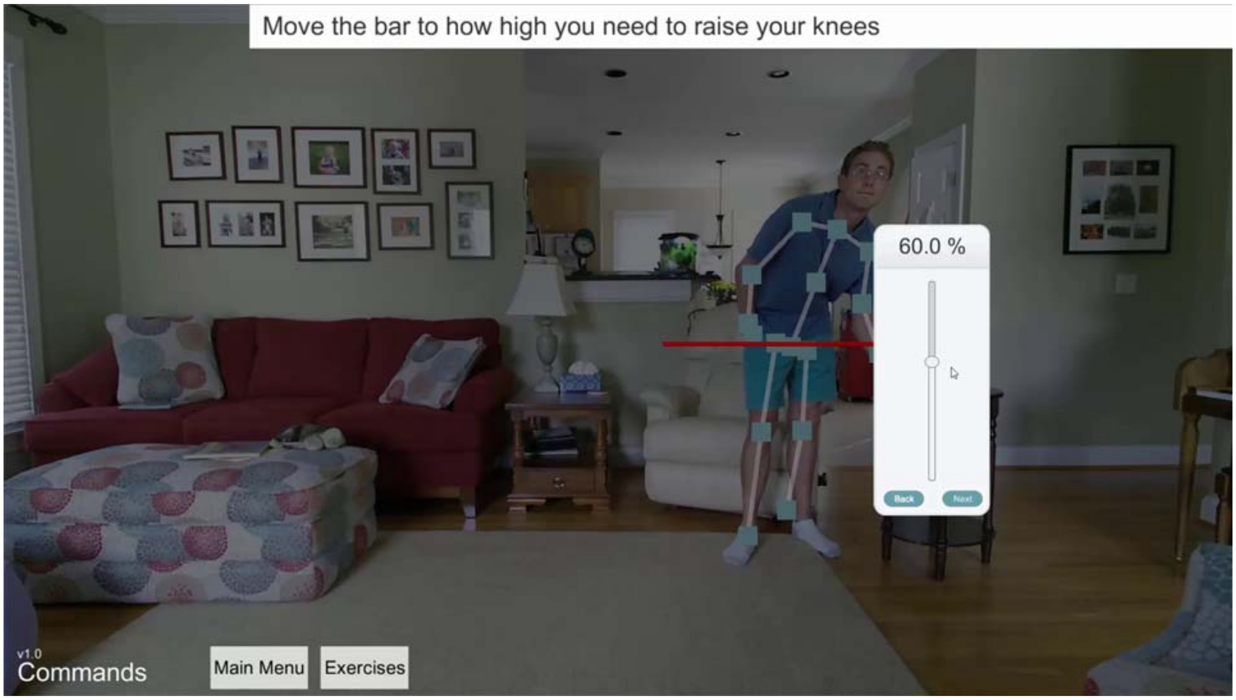


Figure 3: Knee lift knee height setting

Once the exercises have been selected and configured, the patient may run their personal exercise routine through the system. Figure 4 shows the knee lift exercise, with target bar and active leg highlighted. Figure 5 shows the virtual coach feedback during this exercise if the patient begins leaning too much in one direction. We have minimized the on screen interruption of the virtual coach by providing a vertical guide bar, highlighting the torso points of reference, and displaying the corrective message at the top of the screen. The virtual coach counts the repetitions of the exercise up to the pre-configured amount, and then a summary screen recaps the accomplishment, as shown in Figure 6. The exercises may also be completed without the "skeleton" overlay visualization (i.e., the blue boxes and lines between them), as shown in Figure 7.

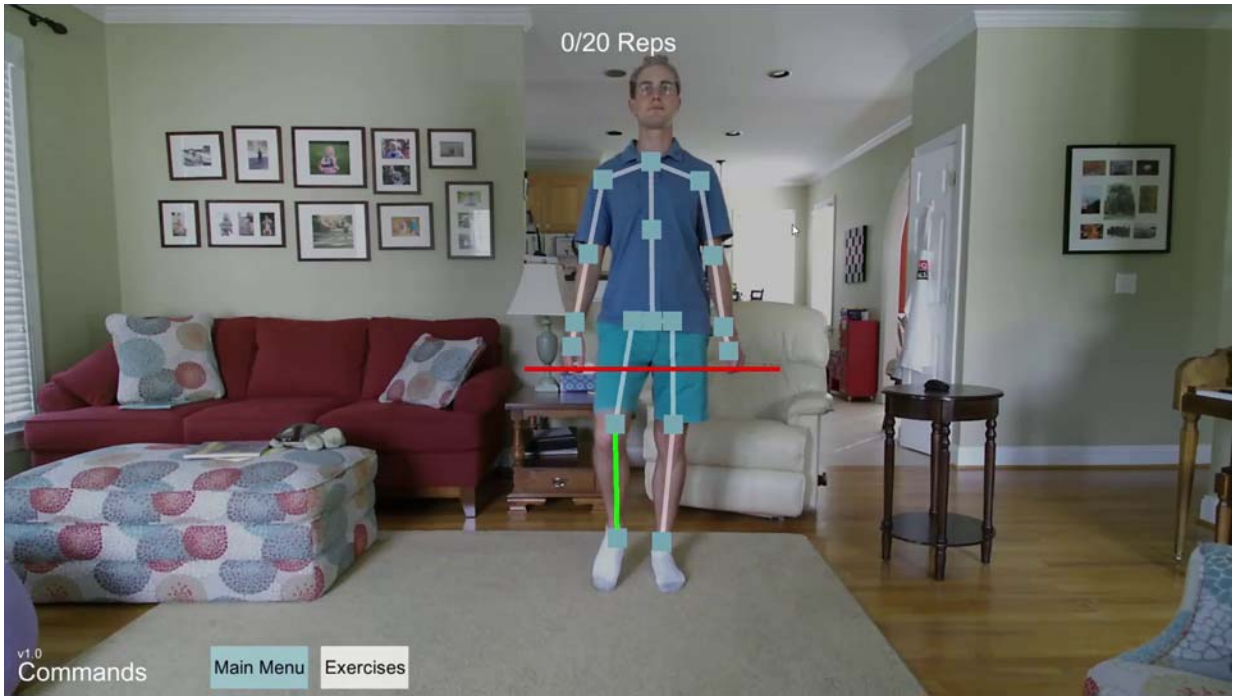


Figure 4: Knee lift exercise

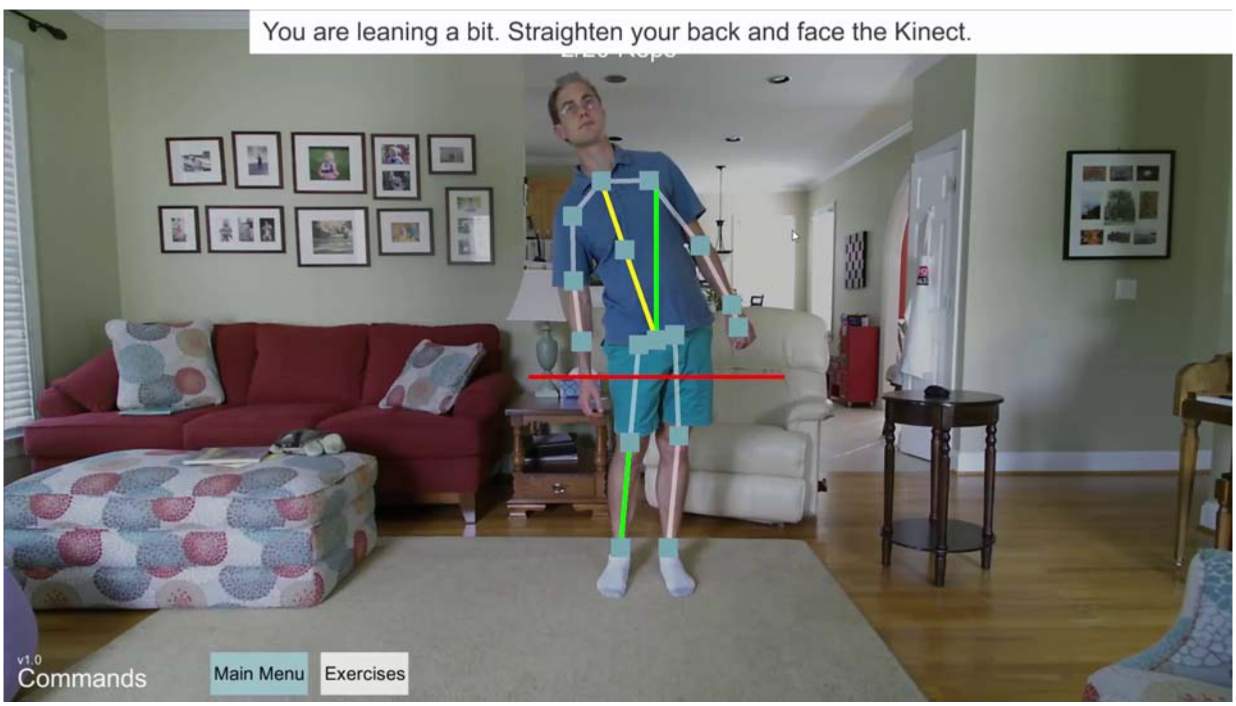


Figure 5: Virtual coach feedback during knee lift exercise

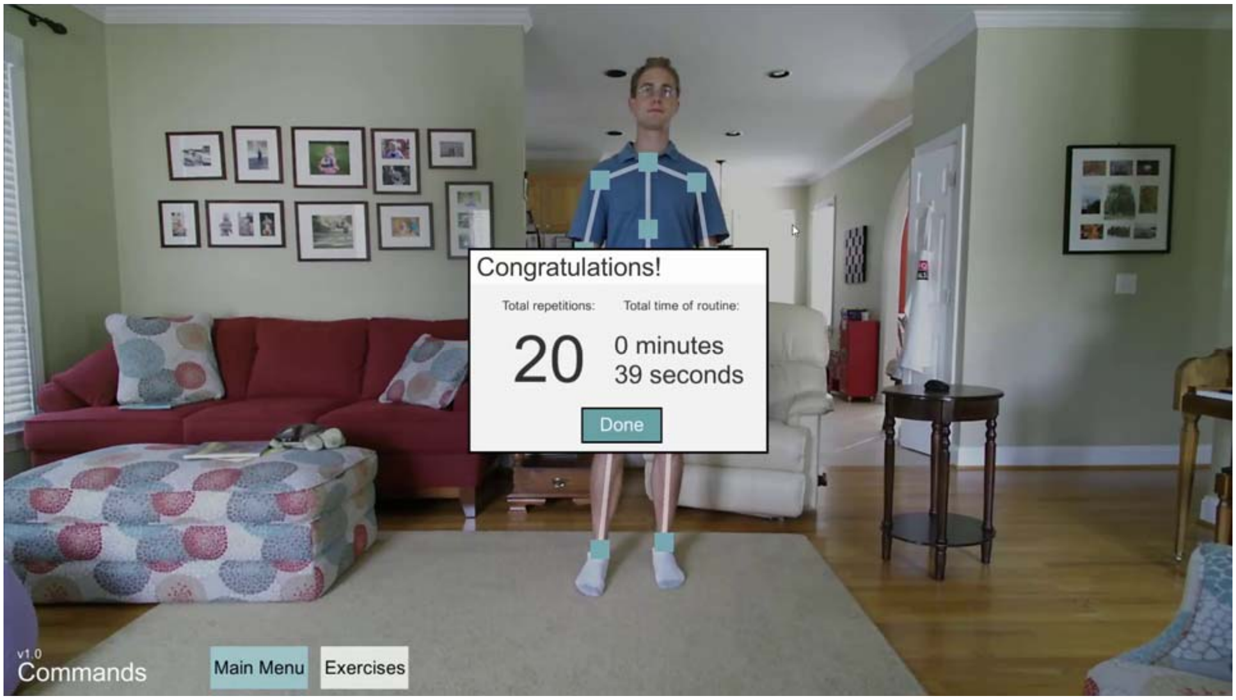


Figure 6: Post-exercise feedback

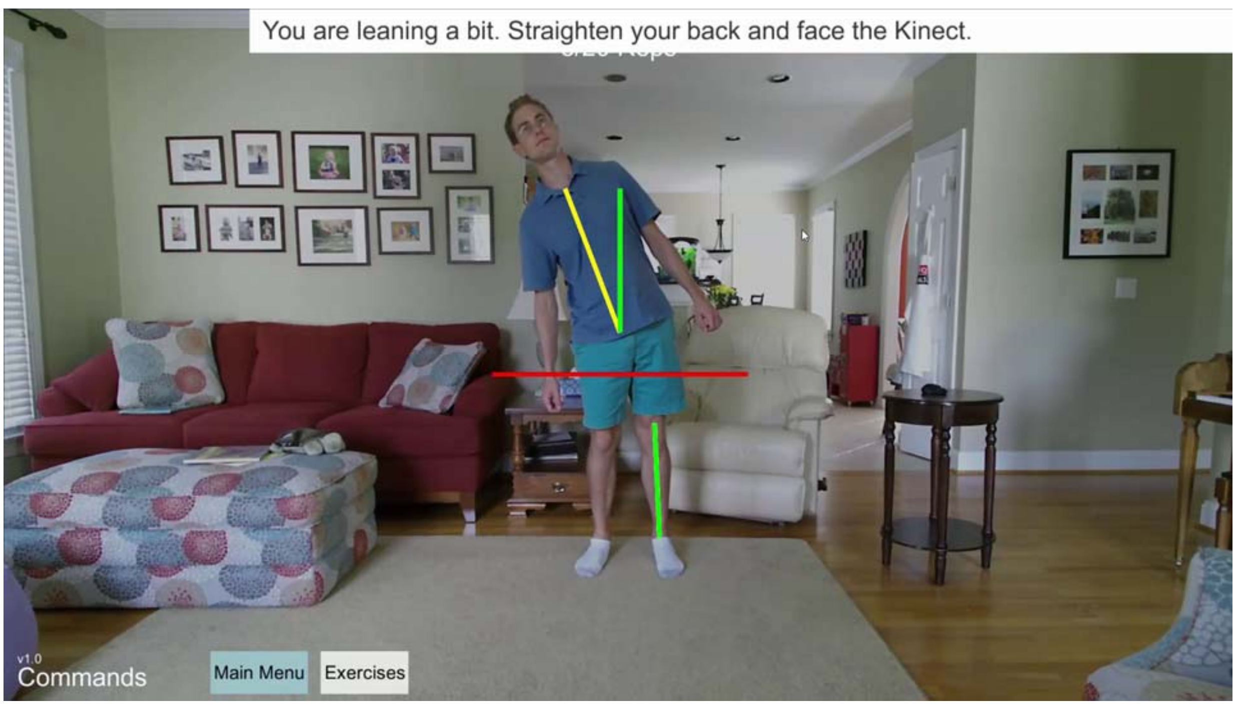


Figure 7: Knee lift exercise and feedback without drawn skeleton

Figure 8 shows the forward lunge exercise, in which the patient must step forward and dip their hips below the red bar. Figure 9 shows virtual coach feedback if the patient leans too far forward and pushes their knee beyond their toes.

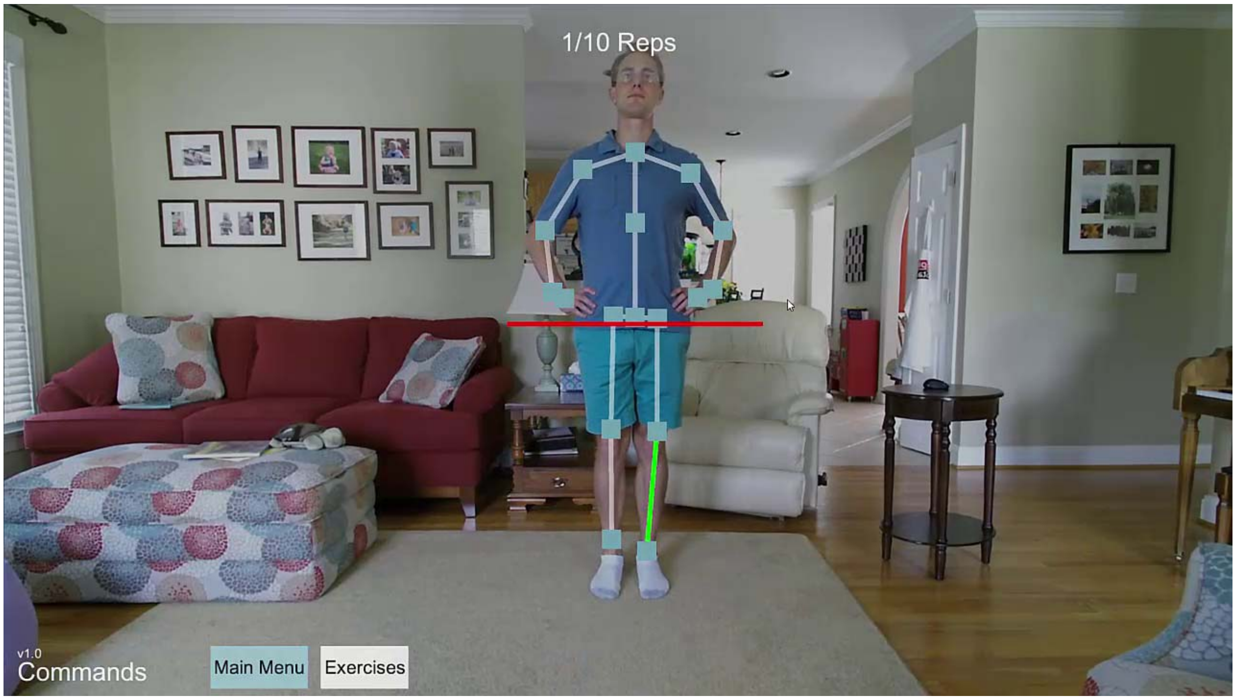


Figure 8: Forward lunge exercise

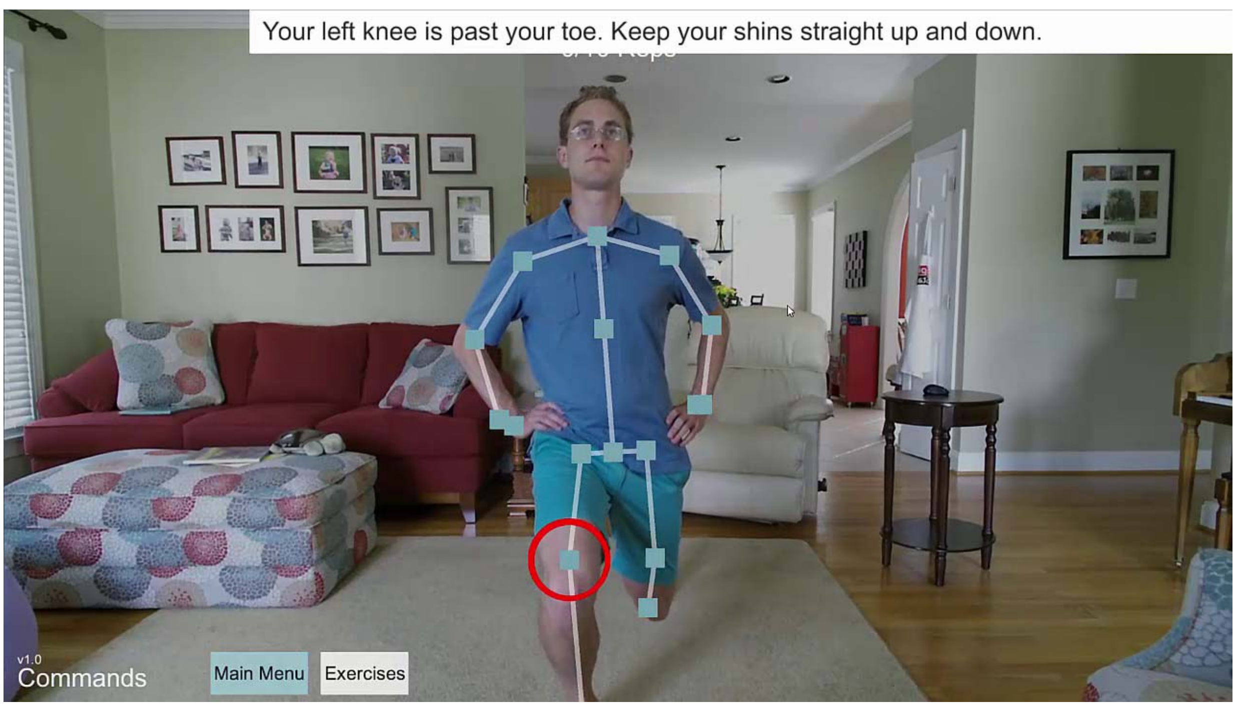


Figure 9: Virtual coach feedback during forward lunge

In addition to the pre-defined exercises, the therapist can walk the patient through a custom recorded exercise. Figure 10 illustrates this feature. This movement is recorded through the Kinect camera and then played back for each repetition for the patient to follow. The white outlines show the patient where to move, and the skeleton is color-coded with green limbs in the correct position and red limbs out of positon.

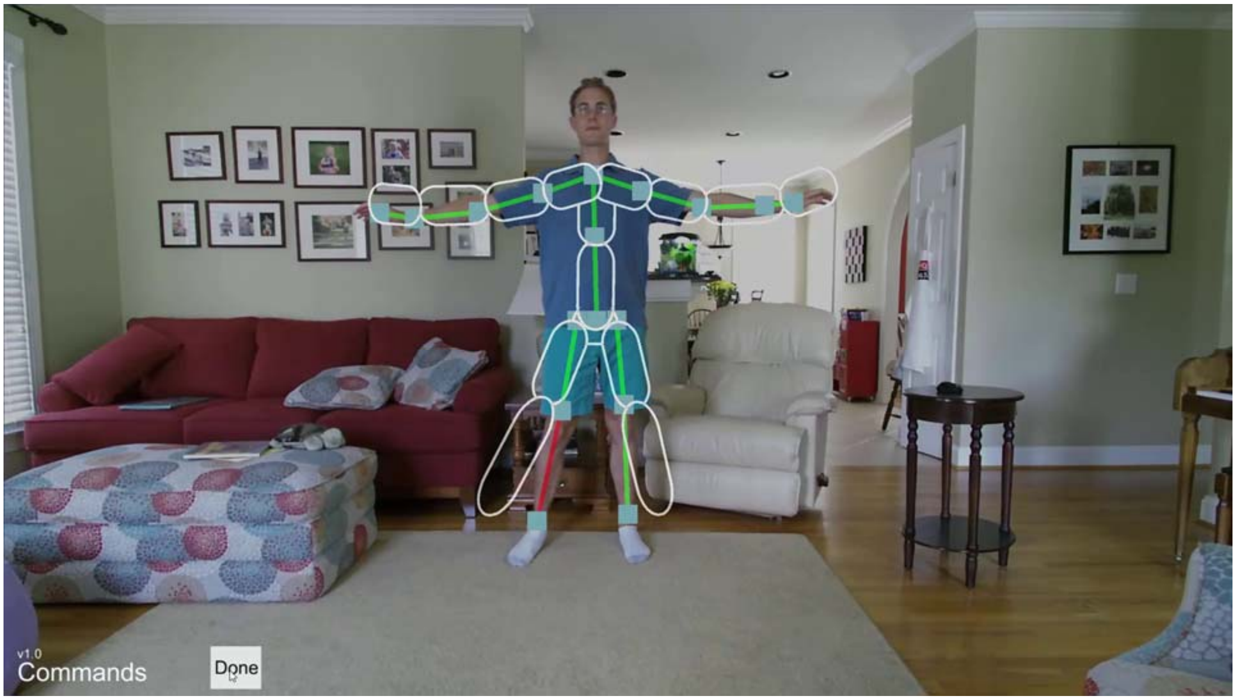


Figure 10: Custom recorded exercise with skeleton coloring feedback

Significant Changes to Technical Approach to Date

There have been no significant changes to the technical approach to date.

Deliverables Submitted This Period

During the current reporting period, we submitted 4 quarterly project status updates to the JPC-1 council.

Milestones Reached/Achieved During This Period

The progress under the above tasks details the milestones achieved this period.

PROJECT PLANS

Specific Objectives for Next Period

- Develop the framework for the patient exercise games

ISSUES OR CONCERNS

We have no technical issues or concerns at this time. As of the time of writing, the option period is yet unfunded, and we are therefore seeking methods to run the initial clinical trials as described in the option period.

EXPENDITURES

Total Contract Amount	$767,388.00
Costs Incurred this reporting period	$96,650.12
Costs Incurred to Date	$593,181.00
Estimated % to completion	75%