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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.

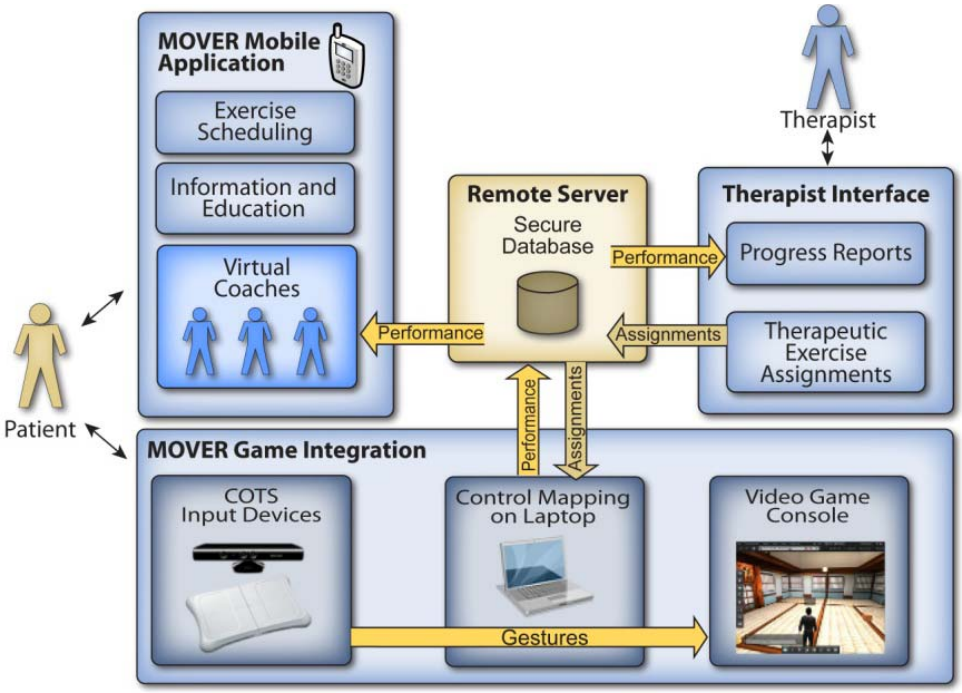
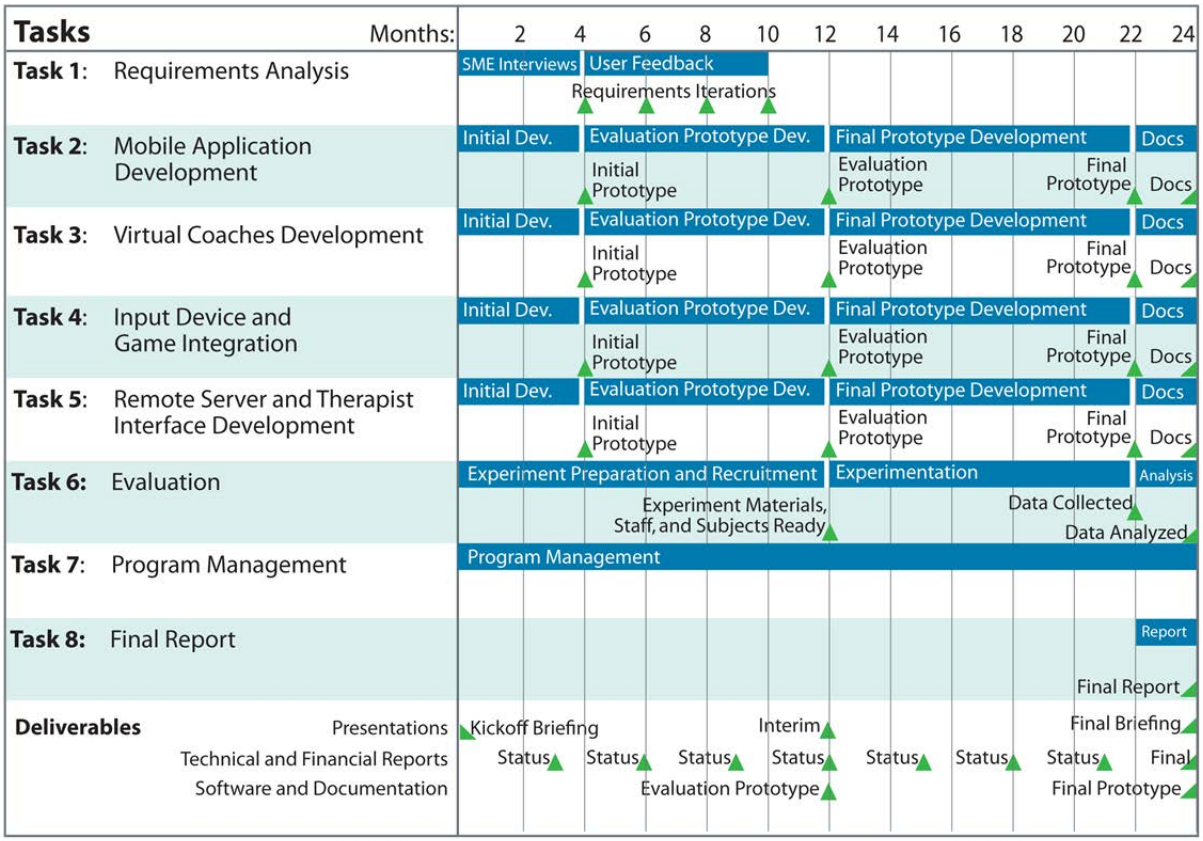


Figure 1: MOVER architecture

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 4 (Input Device and Game Integration), Task 6 (Evaluation), Task 7 (Program Management), and Task 8 (Final Report) as presented in the Statement of Work for this effort.

We attended the Military Health System Research Symposium (MHSRS) and met many members of the operational military health community, including program officers from relevant military labs such as the Congressionally Directed Medical Research Program (CDMRP).

Technical Accomplishments This Period

Task 4: Input Device and Game Integration

Our goal for Task 4 is to integrate commercial-off-the-shelf (COTS) input devices and COTS video games to engage the patient and estimate body posture during therapeutic exercises.

Previously, in reaction to SME feedback, we changed the design of the games in the following ways:

1. We added mouse/clicker support for the menus and removed the voice command requirement.
2. We removed the virtual coach's character from the screen, and removed as much of the overlays as possible while still preserving the core aspects of the exercises.
3. We added a small suite of simple exercise games tuned to motion and balance disorder patients. We made these games highly customizable to enable therapists to tune each game to the capabilities of individual patients.

During the current reporting period, we implemented these design changes in our current prototype. Figure 2 shows the updated main menu screen, and Figure 3 shows the current selection of games. In Figure 4, upon selecting a game, the user is given an introduction to the objectives of the game and the ability to change the specific game settings. The critter swat game is one in which the user stands in the center of the screen and reaches out to swat targets that appear on the screen around them.

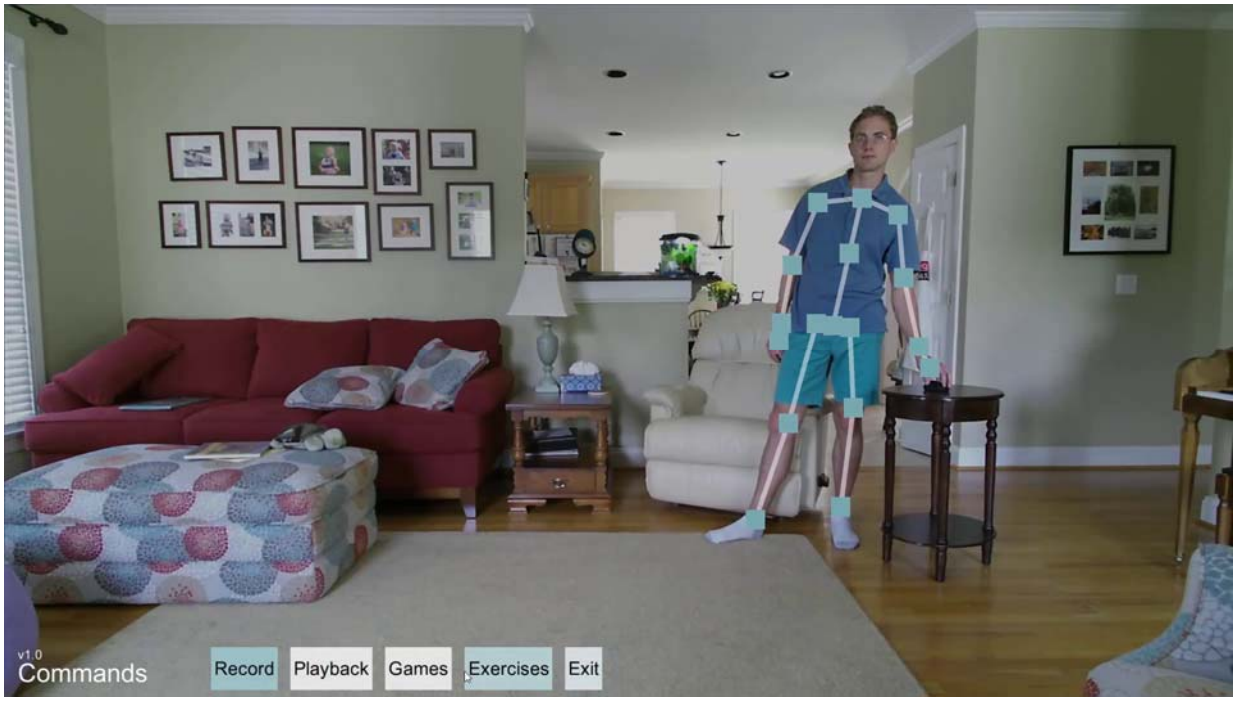


Figure 2: Main Menu Screen

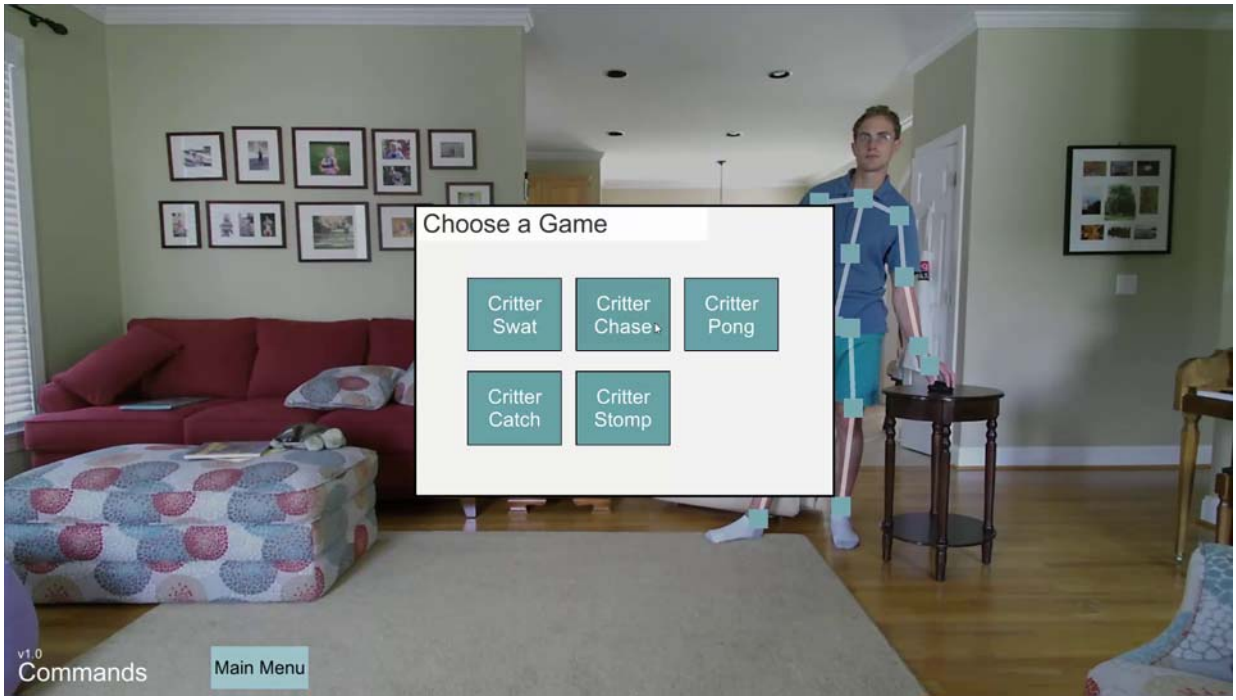


Figure 3: Game Selection

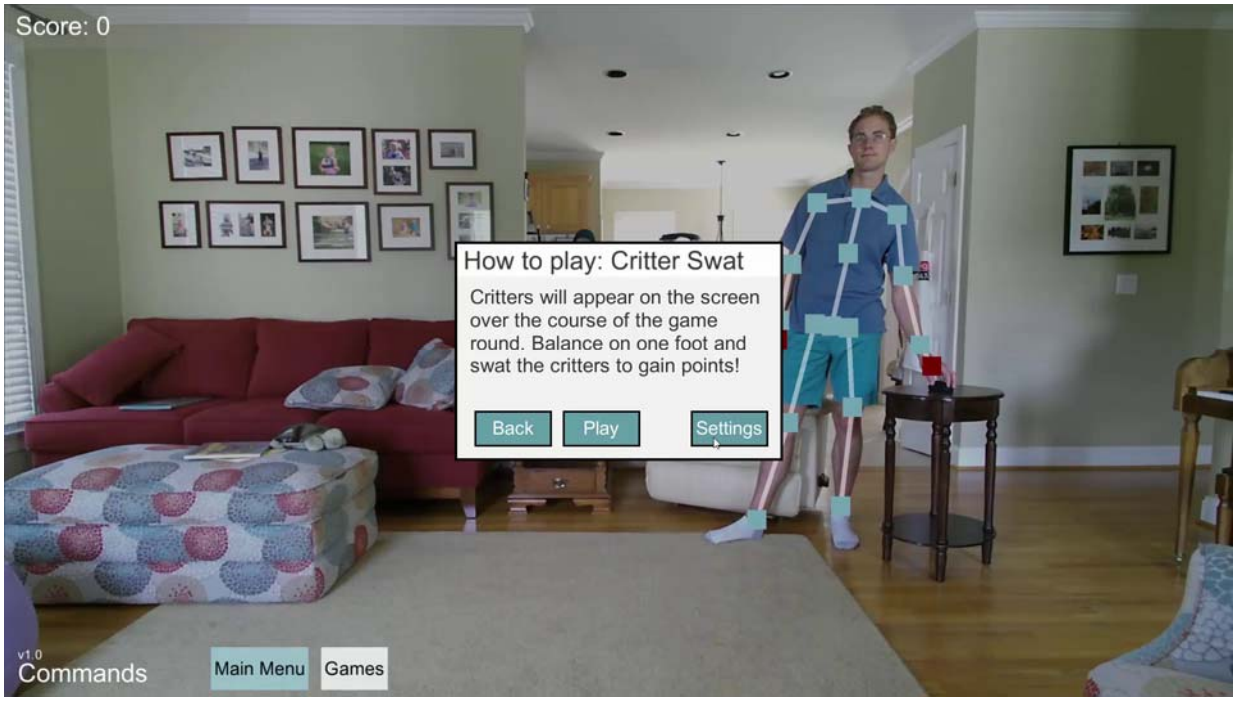


Figure 4: Critter Swat game introduction screen with settings option

Each game includes a host of settings. Figure 5 shows the setting for the target graphic styles. Figure 6 shows the setting for which foot the patient must balance on during the game (left, right, swap halfway through, or both). Figure 7 shows the setting for the length of time the patient must hover over the target before a new target appears. Figure 8 shows the setting for

which hand is allowed to reach for which targets. Figure 9 shows the target spawning location selection screen. The therapist can set this location by enabling the motion selection option and allow the patient to move their hands around the screen. This enables the calibration of the exercise to the areas of the screen that the patient can reach without moving. Figure 10 shows the game duration settings.

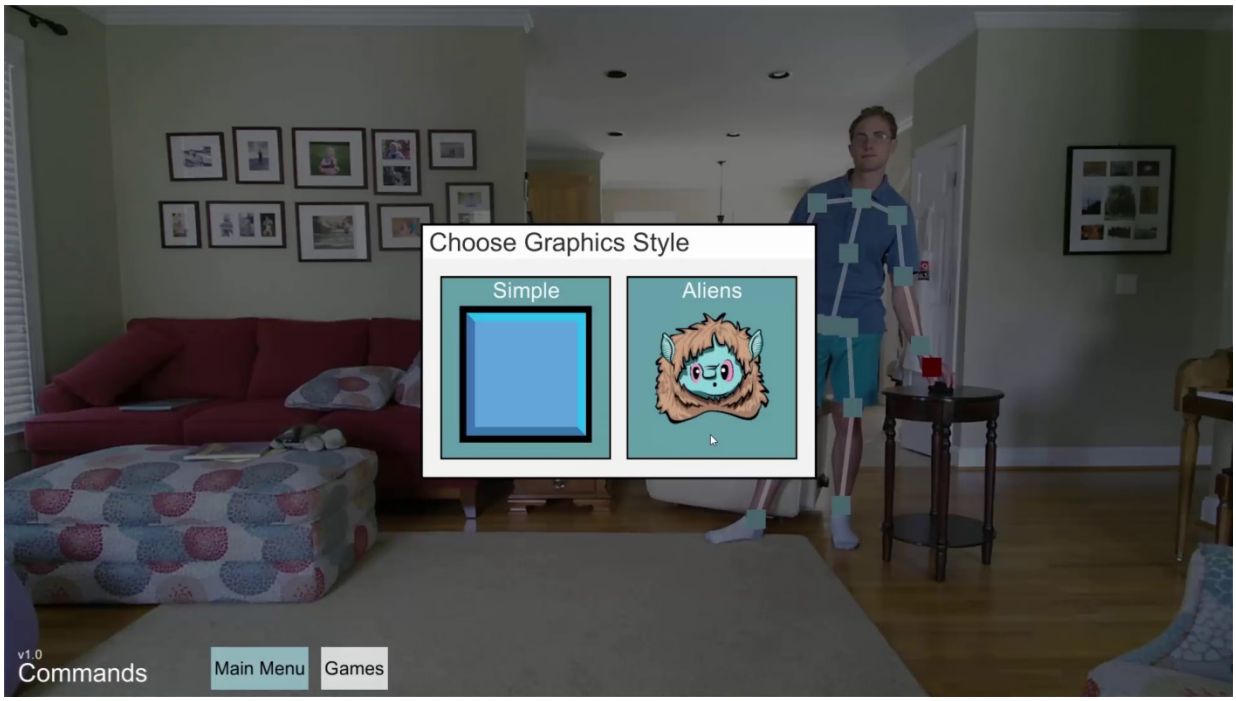


Figure 5: Graphics style settings

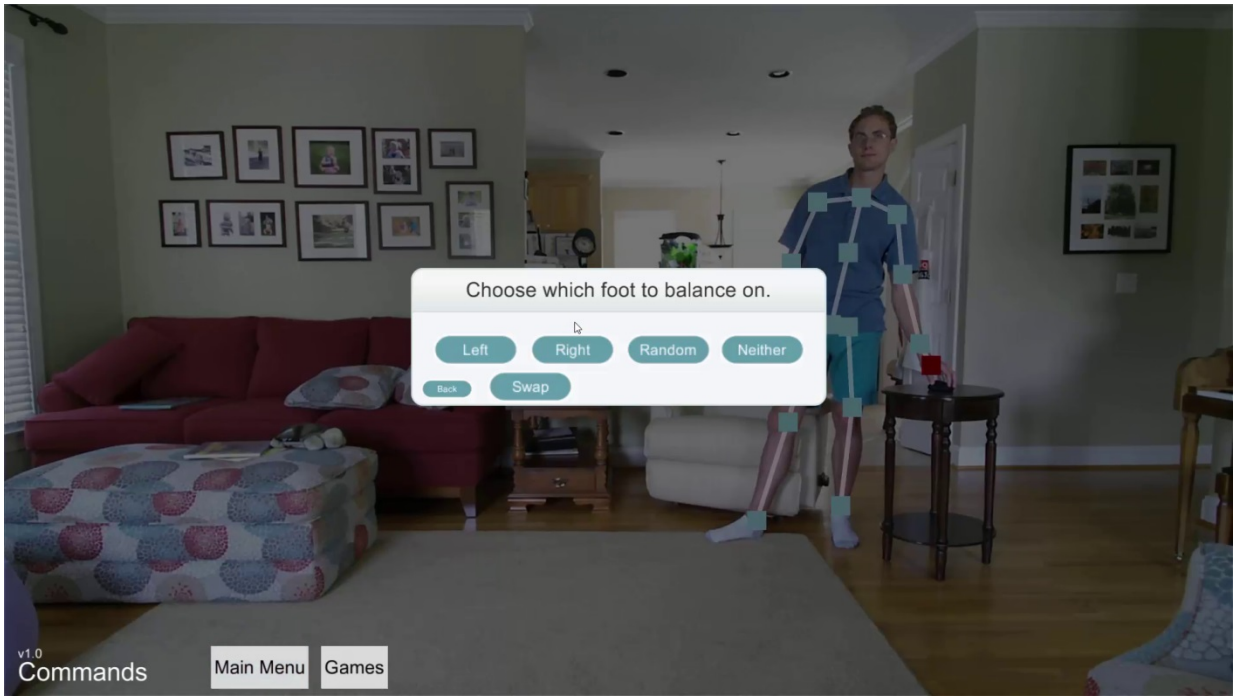


Figure 6: Foot balance settings

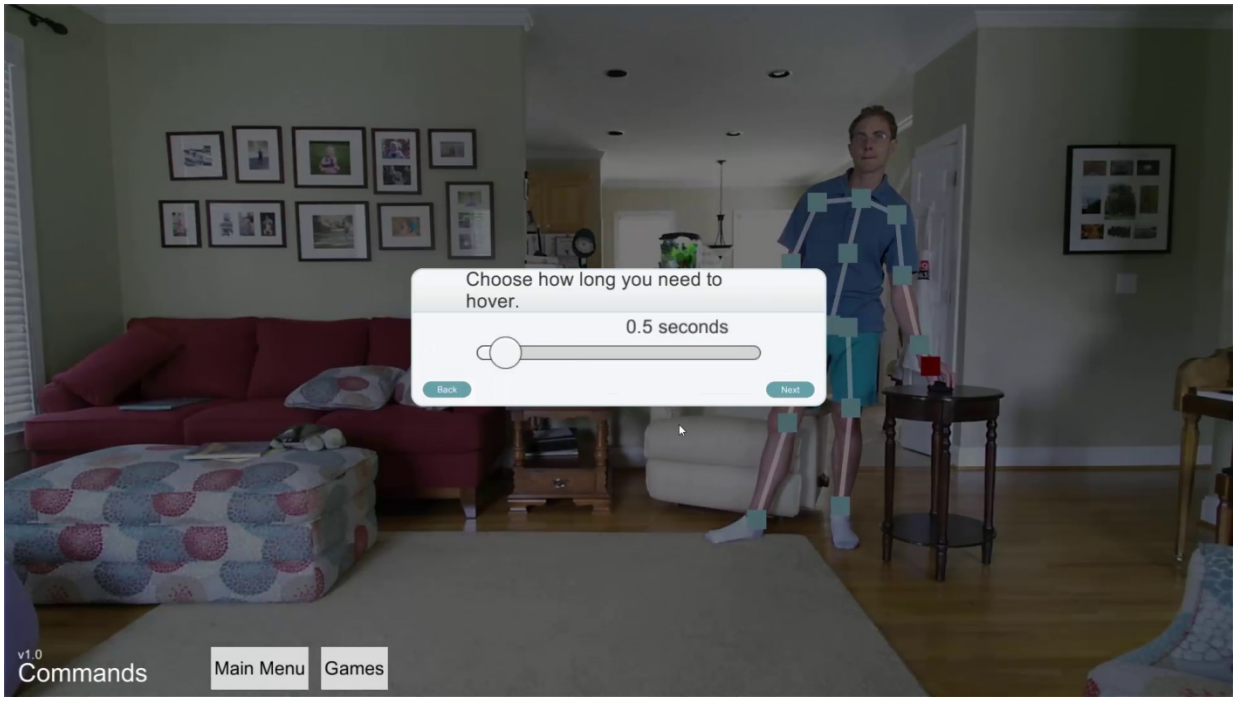


Figure 7: Hover length settings

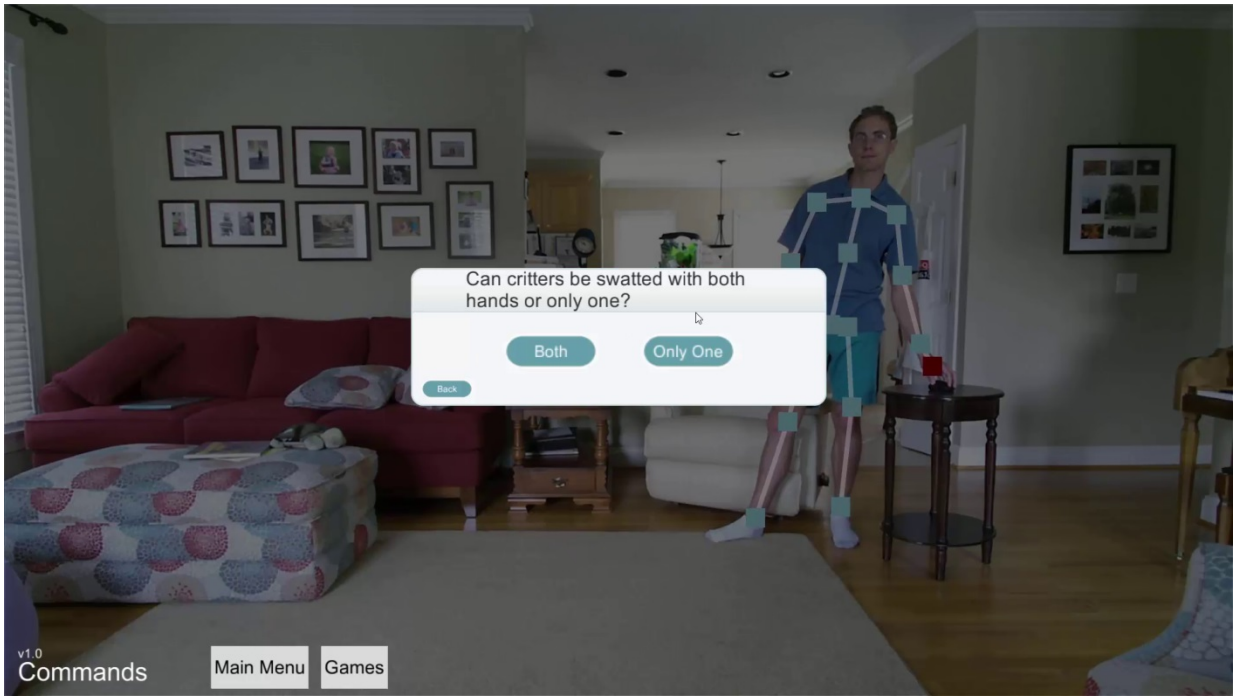


Figure 8: Hand use settings

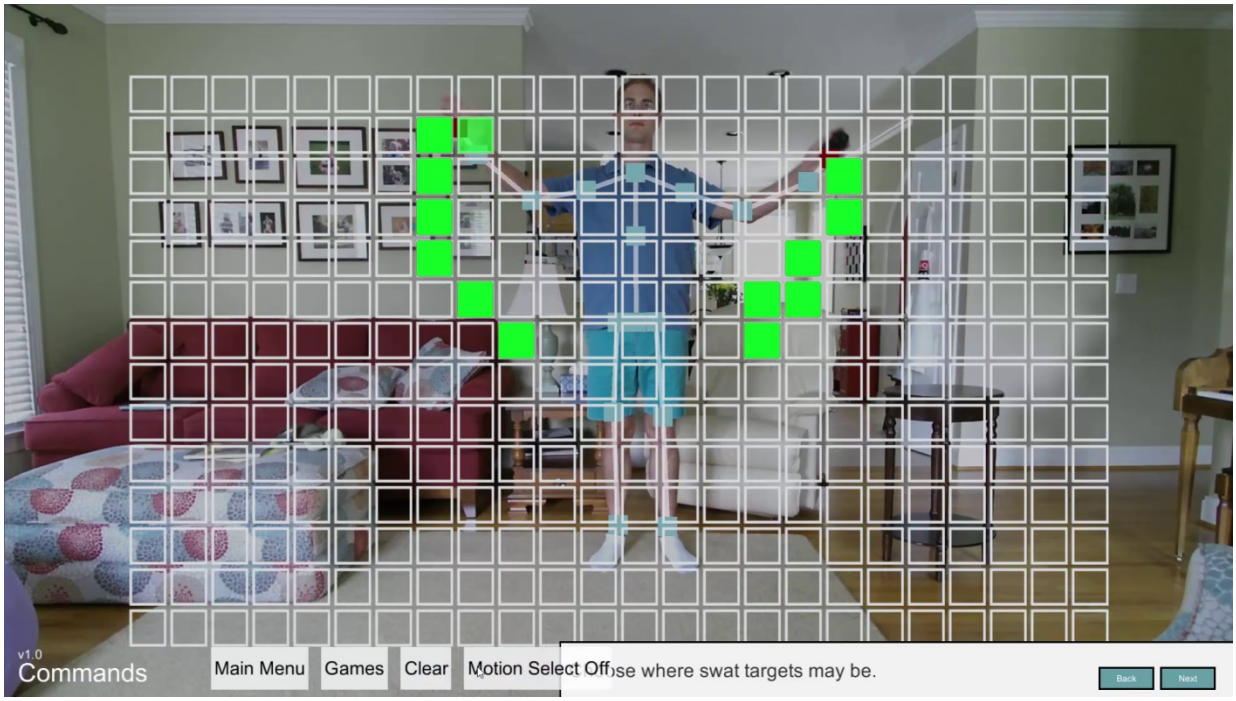


Figure 9: Target location settings

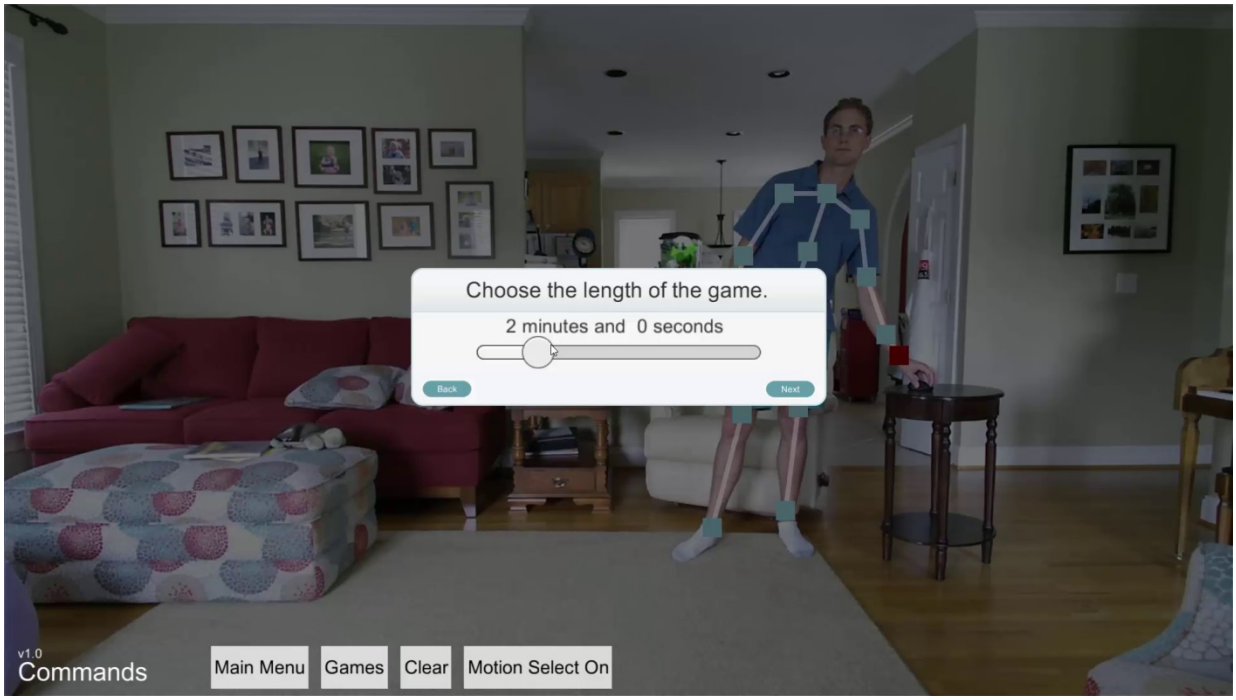


Figure 10: Game duration settings

Playing the games is similar to performing the exercises. In Figure 11 and Figure 12, the patient is instructed to stand in the center of the screen to begin the critter swat game. In Figure 13, the patient plays the critter swat game by reaching and hovering their hand over targets. In Figure 14, after a set amount of time the game ends and the user is presented with their high score, giving them feedback on their progress.

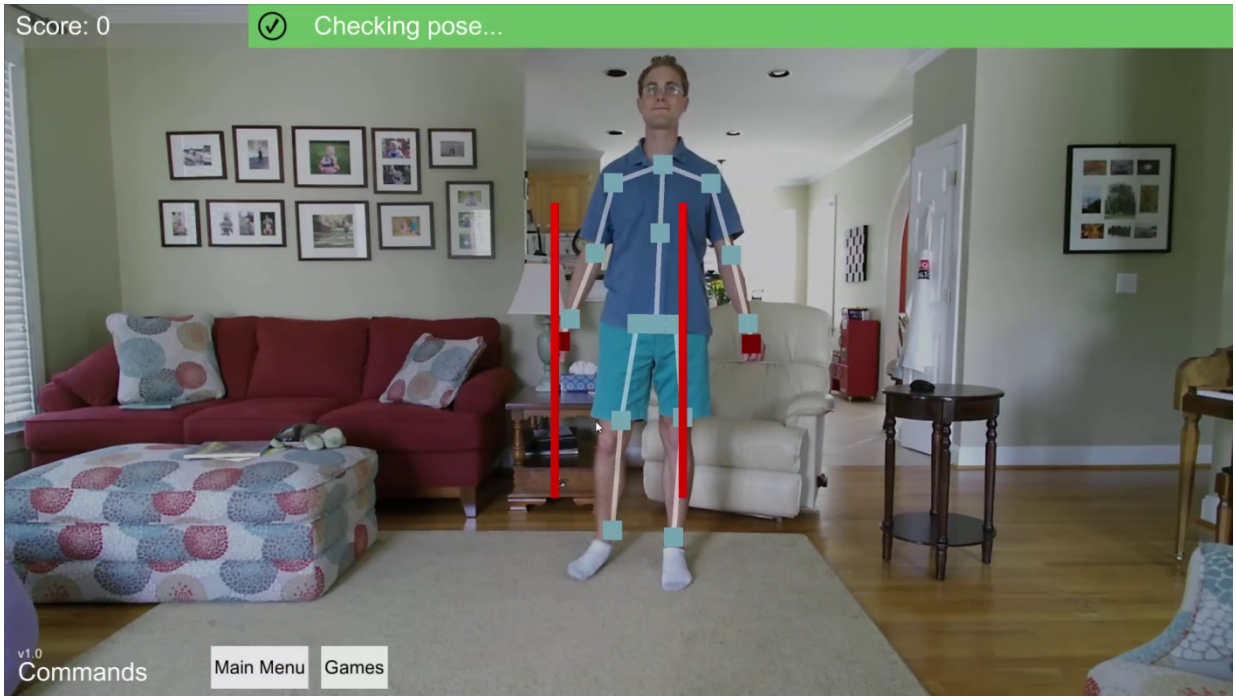


Figure 11: Critter Swat pregame checking location and pose

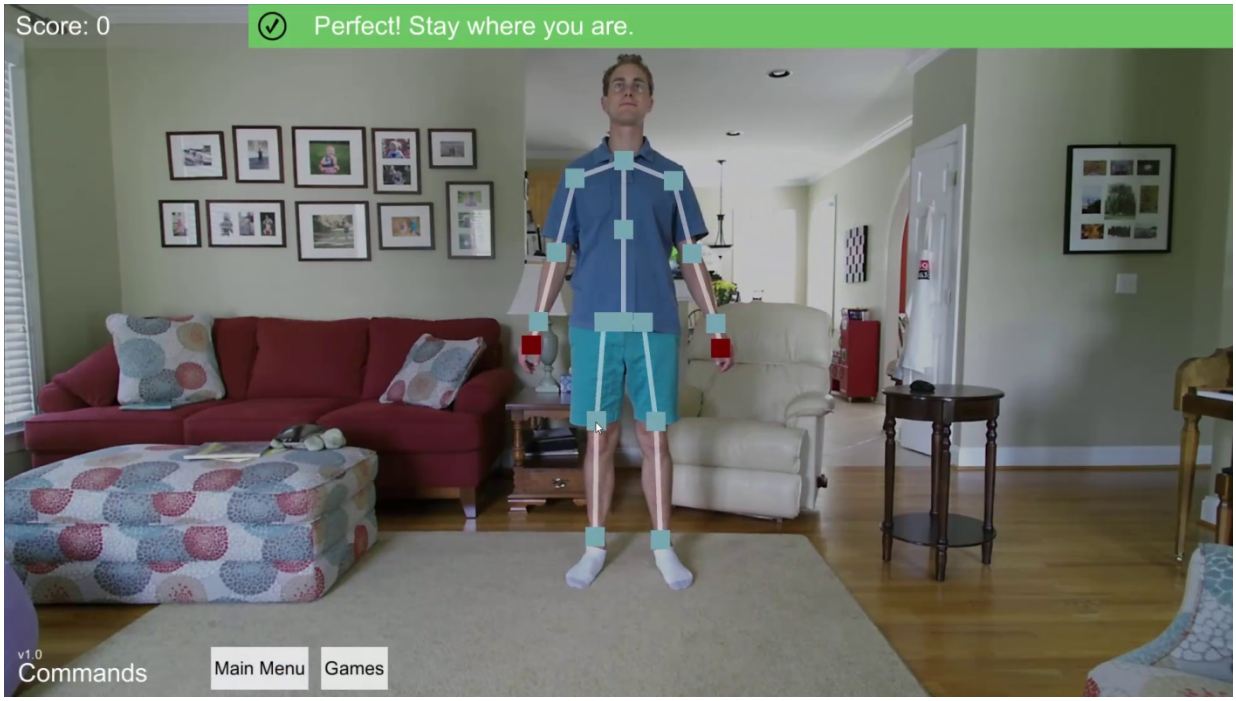


Figure 12: Critter Swat game location and pose achieved

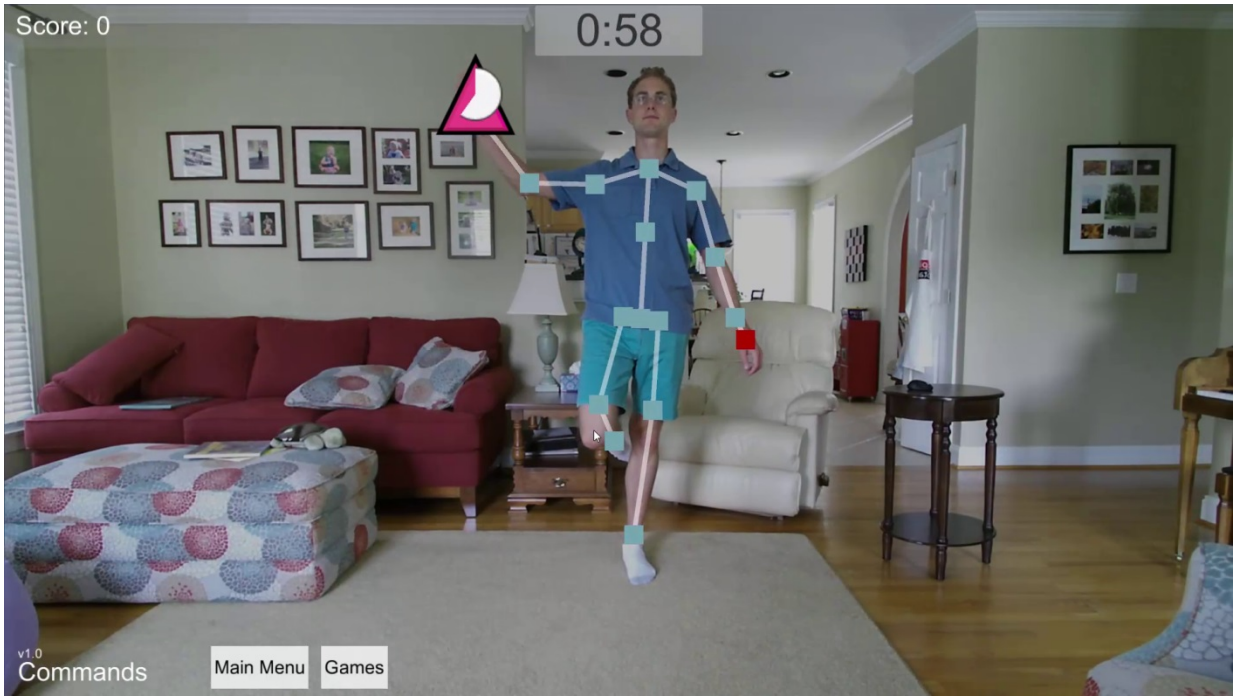


Figure 13: Critter Swat game

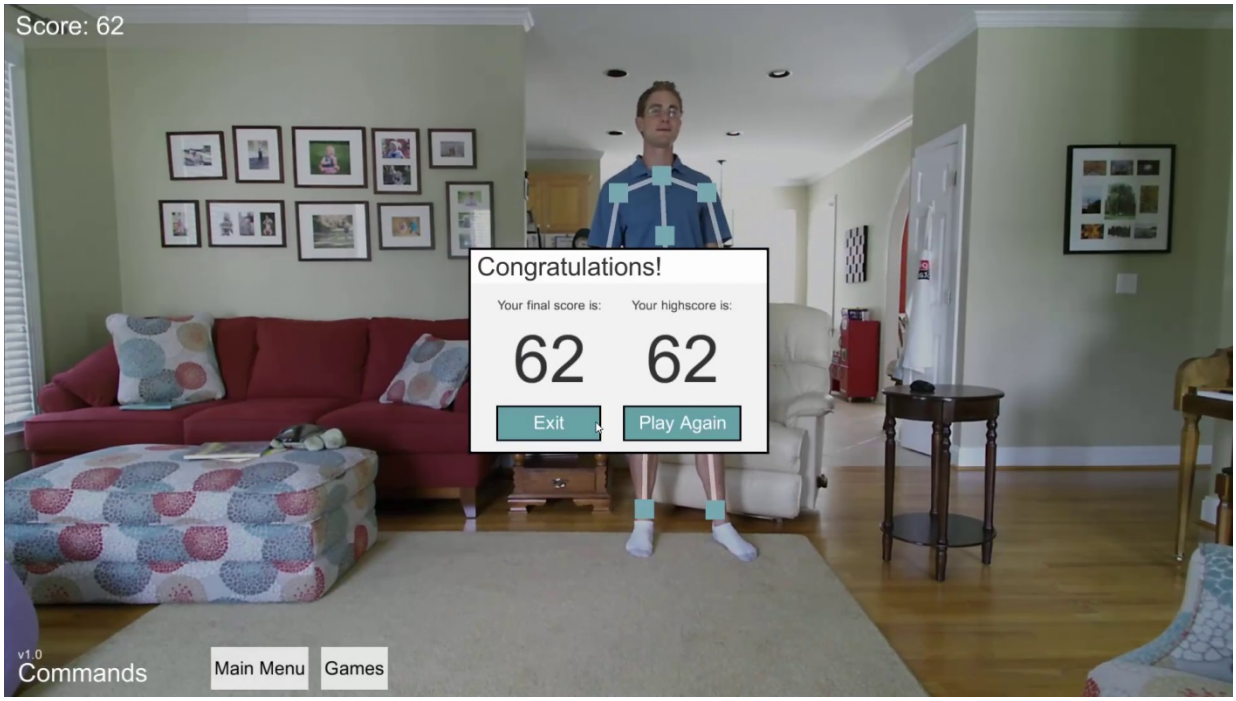


Figure 14: Critter Swat end round and high score screen

We implemented multiple games during the current reporting period. In Figure 15, patients play the critter chase game by roaming around the exercise area and hovering over targets that

appear on the screen. In Figure 16 and Figure 17, patients play the critter stomp game by waiting for the targets to enter the screen from the left or right, raising their leg above the configurable red bar, and stomping the target as it comes by. In Figure 18, patients play the critter catch game by shifting left or right underneath the targets falling from the top of the screen to catch them before they fall to the bottom. In Figure 19, each of the games feature feedback if the patient breaks the desired posture. The game pauses to wait for the patient to readjust. In Figure 20, patients play the critter pong game by swatting the targets away as they bounce from the left or the right of the screen.

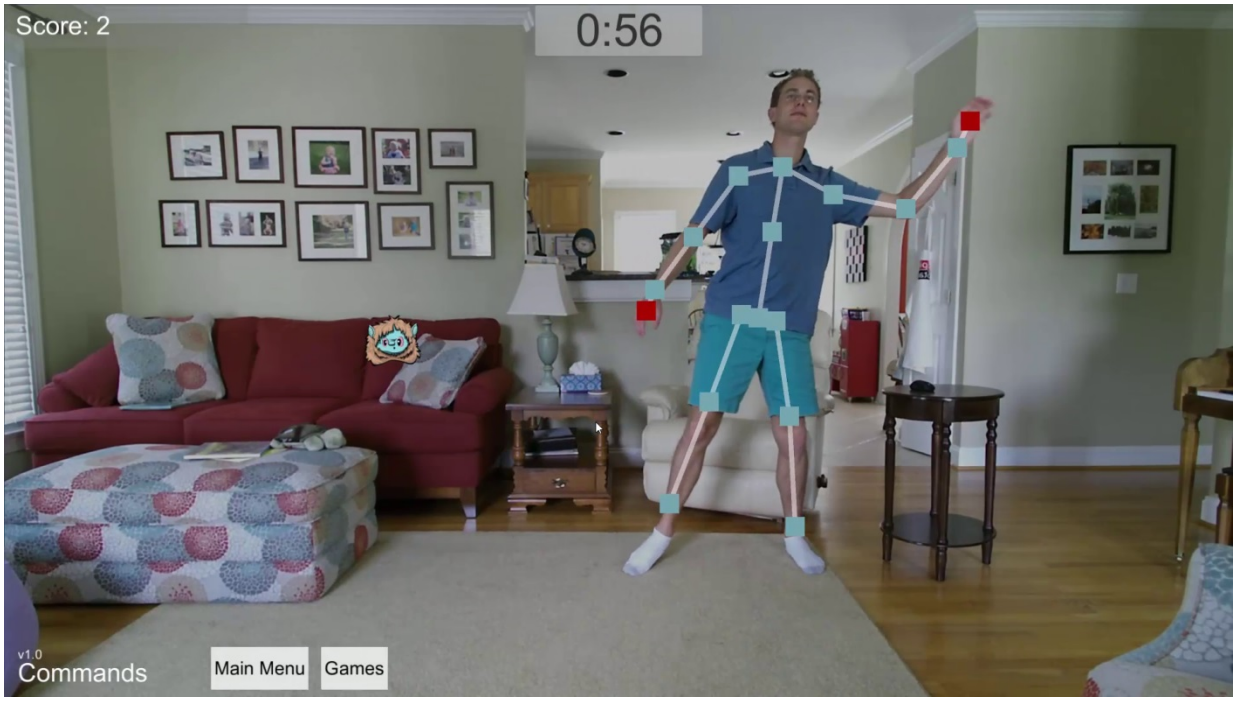


Figure 15: Critter Chase game

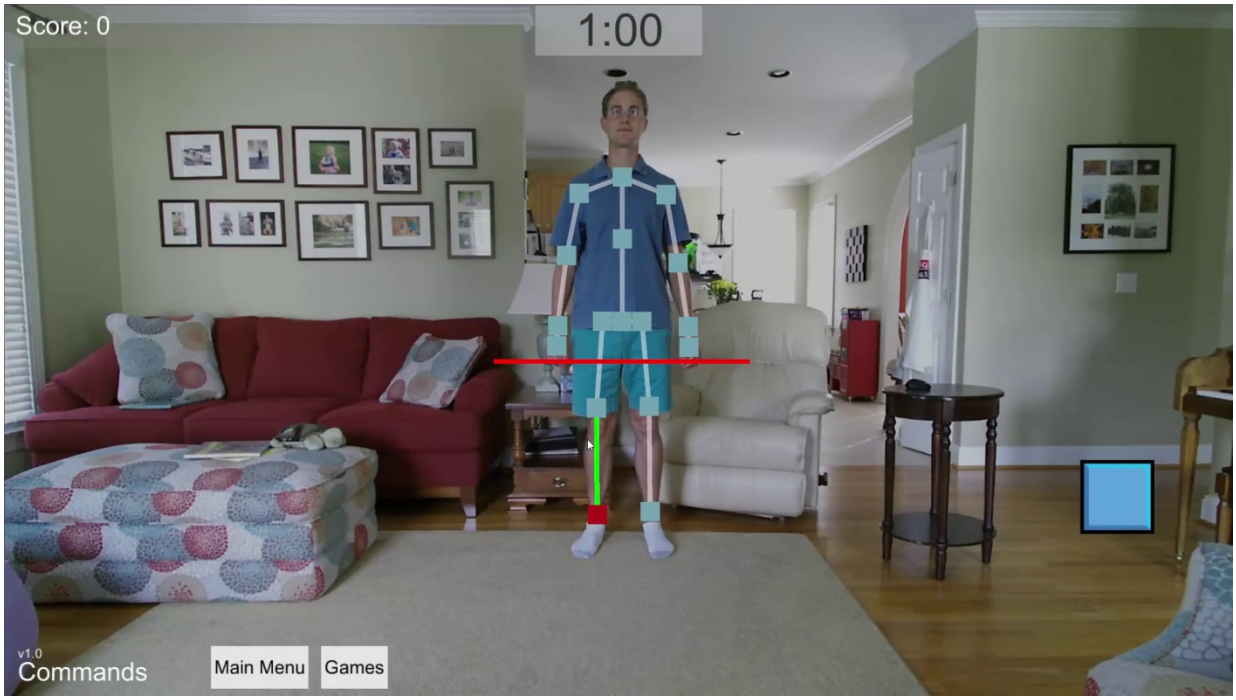


Figure 16: Critter Stomp game, target approaching from right

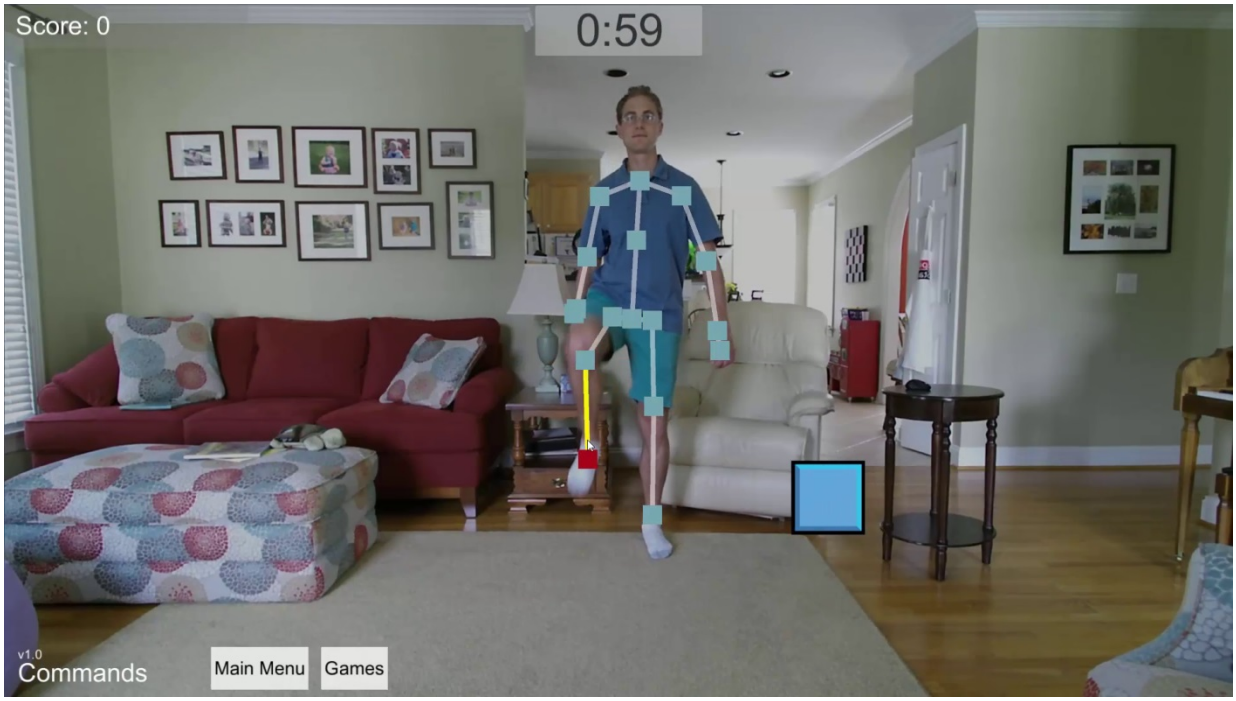


Figure 17: Critter Stomp game, leg raised for stomp

Figure 18: Critter Catch Game

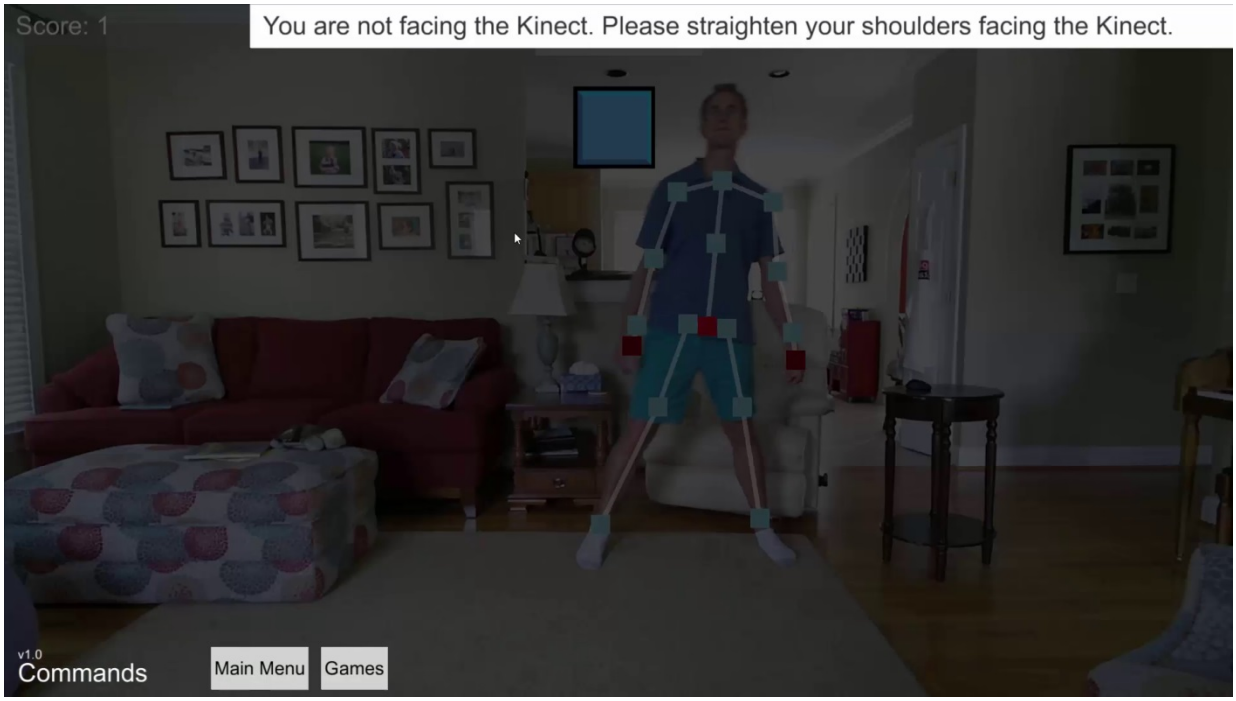


Figure 19: Critter Catch feedback

Figure 20: Critter Pong game

Task 6 (Evaluation)

The purpose if this task is to evaluate the MOVER system through a pilot study, to be performed if the Option is funded. During the current reporting, we have planned the pilot study of MOVER in the Spaulding facilities, determined our measures, and revised our IRB application to recruit and collect this data. We have requested a no-cost time extension to the effort to be able to execute this study. If this extension is approved, we will proceed with the study.

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

- Complete the final report

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	$138,398.36
Costs Incurred to Date	$731,579.36
Estimated % to completion	95%

Appendix A: MOVER Poster Presentation

Mobile, Virtual Enhancements for Rehabilitation (MOVER)

charles river analytics

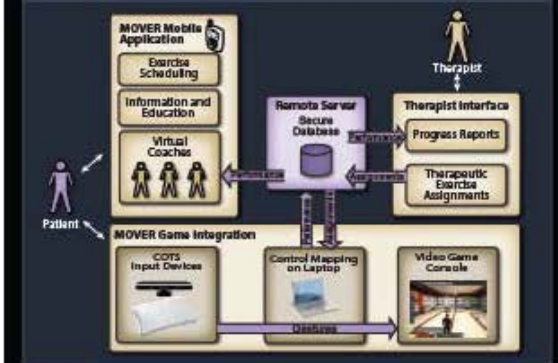
Charles River Analytics, Inc.: James Riehaus, PhD (PI), Peter Weyhrauch, PhD, Jonathan Hsu, Bishop Myers, Joe Lavoine, David Young

Spaulding Rehab Hospital: Paolo Bonato, PhD, Seth Herman, MD, Catherine Adans-Dester, PT, Anne O'Brien, PT, Joyce Liu, PT, Ross Zafonte, DO

Abstract: MOVER is a system to reduce the cost and increase the effectiveness, availability, and accessibility of Warfighter physical rehabilitation. MOVER features: (1) virtual coaches to provide interactive guidance and mentoring; (2) integration with commercial 3D sensors to track patient movements; (3) integration with commercial video games to target cognitive impairments and increase motivation; (4) a mobile application to provide education and information; and (5) a therapist interface to accurately report patient progress.

Benefits: Lengthy inpatient treatments are extremely costly, especially for complex conditions such as traumatic brain injury (TBI), and they are not available to all patients. MOVER being developed to enhance outpatient rehabilitation, improving the quality, effectiveness, and cost efficiency of these interventions. Ultimately, this enables military health systems to provide more and better care for injured Warfighters.

Architecture

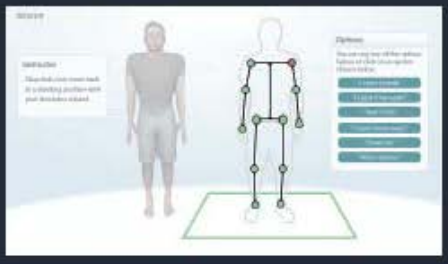


Therapy Targets

Current focus on traumatic brain injury (TBI)-induced motor and balance limitations

- Lengthy inpatient treatments are costly* to MTFs and VAMCs,
  ultimately reducing number and types of services offered
- Outpatient treatments are available, however
- Not widely used for all rehabilitation interventions
- Patients often lack adherence due to
- confusion about exercises
- perceptions of lack of time
- forgetting
- perceptions of helplessness
- overall lack of motivation (Jette et al., 1998; Sluijs, Kok, & van der Zee, 1993)

Interaction



Current Development Build

Acknowledgment: This material is based upon work supported by the United States Army Medical Research and Materiel Command under Contract No. W81XWH-13-C-0021.

Appendix B: MOVER Quad Chart

Revolutionary Research . . . Relevant Results

Mobile, Virtual Enhancements for Rehabilitation (MOVER)

Charles River Analytics, Inc. | PI: Dr. James Niehaus

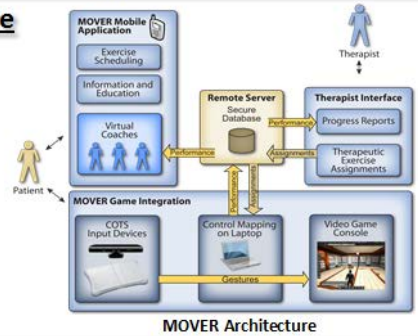
Summary

Problem: Today's warfighters are sustaining physical and cognitive wounds that require prolonged rehabilitation protocols. Inpatient delivery of treatment is expensive and manpower intensive; outpatient delivery relies on the patient to be sufficiently motivated and educated to "self-administer" the required rehabilitation protocols.

Solution: MOVER is a mobile, technology-enabled home-based rehabilitation intervention delivery system. The increased education, motivation, and support provided by MOVER will increase adherence to outpatient therapies, thereby reducing total rehabilitation costs and helping to ensure the success of out-patient rehabilitation interventions.

FY13	FY14	FY15
$153,677	$481,868	$364,041

Core



MOVER Architecture

How it works

To provide education and information and to schedule therapeutic exercises:

- MOVER features mobile application for a smartphone or mobile device.

To provide interactive guidance and mentoring:

- MOVER features virtual coaches that appear on the mobile application.

To increase patient motivation, enable monitoring of patient progress, and reduce cost of deployment to the home environment:

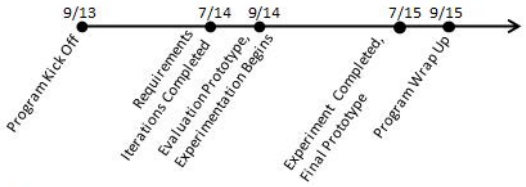
- MOVER provides a COTS technology-based multi-modal interactive environment for the patient to practice therapeutic exercises at home.

To enable therapists to accurately assess patient adherence and progress:

- MOVER provides printable summary reports of patient exercises through a web-based interface.

Programmatics

Period of Performance: 24 Months



Deliverables:

- Quarterly: Technical and financial progress reports
- Annually: Technical reports
- At contract completion: Technical report and final software prototype with therapist user manual and supporting hardware.