NextGen Crew Countermeasure Software for Exploration Mission Support

2017 NASA Human Research Program Investigators' Workshop Galveston Island Convention Center

January 23-26, 2017

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Objectives

- Develop and integrate new instructional, motivational and socialization techniques with improved interfaces with the aim of reducing or preventing bone and muscle deconditioning and improving the overall physical and psychological conditioning and performance of the crew while on-orbit or on other terrestrial surfaces.

- Specifically, this project proposal will test whether, 1) improving the usability of crew interface software to exercise CMS through common app-like interfaces, 2) introducing instructional motion training, and 3) incorporating socialization through a virtual environment with family and friends, will improve exercise technique, adherence, and performance outcomes.

- Fundamentally, this is a software architecture design project that will establish the groundwork for standardization of the proposed multi-component, multi-faceted software architecture for all future exploration class exercise equipment.
Specific Aim 1: Software Usability

- Software interface system to be standardized across the astronaut exercise devices (both aerobic and anaerobic, including an ergometer, treadmill, rower or strength training hardware)
- Address usability, satisfaction and efficiency with objective metrics and questionnaires contrasting new interface with current interfaces.
- Minimize astronaut training needs, utilize the latest GUI designs focused on intuitive ease of use approach (80% of the functionality gained within 5-10 minutes of use).
- Each phase of the usability testing will be conducted with at least 10 participants, the goal is to find design concerns of the user interface.
- To evaluate the user interface, we will conduct iterative usability testing. The purpose is to find any interface design issues that can cause errors, frustration, and could increase task time.
Evaluation Tools

• To evaluate the user interface, we will conduct iterative usability testing.
• Testing will consist of asking users to complete high frequency or high criticality tasks related to the system and capture their performance (e.g., error, task time) and subjective comments.
• Errors and task time will be recorded during the testing sessions by the system or the test conductor.
• Subjective comments will also be collected during the usability studies by asking subjects to think aloud while completing the tasks.
• The issues will be ranked based on frequency and severity. The errors and comments will help to identify design problems that can be corrected for the final software interface.

System Usability Scale (SUS)

Please rate the following items on a 5-point scale, 1 being strongly disagree, and 5 being strongly agree.

<table>
<thead>
<tr>
<th>Item</th>
<th>Scale 1</th>
<th>Scale 2</th>
<th>Scale 3</th>
<th>Scale 4</th>
<th>Scale 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I think that I would like to use this system frequently</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. I found the system unnecessarily complex</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. I thought the system was easy to use</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. I think that I would need the support of a technical person to be able to use this system</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. I found the various functions in this system were well integrated</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. I thought there was too much inconsistency in this system</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. I would imagine that most people would learn to use this system quickly</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8. I found the system very cumbersome to use</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9. I felt very confident using the system</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>10. I needed to learn a lot of things before I could get going with this system</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

For odd items: subtract one from the user response.
For even-numbered items: subtract the user responses from 5.
This scales all values from 0 to 4 (with four being the most positive response).
Add up the converted responses for each user and multiply that total by 2.5. This converts the range of possible values from 0 to 100 instead of from 0 to 40.

Resistance exercise is needed to maintain proper health during space flight but with poor technique, especially in spinal loading exercises, can result in serious injuries. 
- **Ex. Rounded back during deadlifts can result in disc herniation**

For long duration spaceflight, exercise feedback from ground support may become more challenging due to communication delays.

The Kinect can track the 3D position of 26 skeletal joints using an infrared camera which can be used to display, record and instruct the crewmember on repetition consistency in multiple joint movements reducing the incidence of injurious exercise technique.

**Objective:** Develop a tool that can provide real-time instruction and correctional feedback for crew members in the absence of real-time ASCR support during exercise to prevent avoidable injuries and optimize overall muscle strength outcomes.

**Hypothesis:** Subjects who have access to the instructional software tool with real-time kinematic feedback will perform resistance exercise with more appropriate and consistent technique than those without the instructional software.
Exercise Instruction and Feedback Software

- The software tool uses the Kinect to provide real-time user feedback and corrects any mechanical errors that could result in injury.

Current features:
- A real-time sagittal view of the joint positions
- Provides a personalized silhouette for the user to follow during exercise
- Voice activation
- Corrective feedback determined by AdaBoost motion learning algorithms

Remaining work:
- Refine user interface
- Expansion of motion learning database
- Usability and feasibility testing
Study Design Specific Aim 2

20 Subjects

Session 1 – Familiarization Session

Session 2 – 1RM Determination and Kinematic Data Collection (pairing)

Randomized

Session 3: 3x5 at 80% 1-RM

Session 3: 3x5 at 80% 1-RM

Session 4: 3x5 at 80% 1-RM

Session 4: 3x5 at 80% 1-RM
Specific Aim 3: Test the integration of an existing virtual reality software tool for its effectiveness to improve performance in a single bout of high intensity exercise, and adherence during a one-month metabolic conditioning program.
Study Design Specific Aim 3

Hypothesis 3A
- 20 Participants
- VO2 Max Test
- Timed-run to-failure (with music and software)
- Timed run-to-failure (with music alone)
- Timed run-to-failure (with nothing)

Hypothesis 3B
- Vo2 Max Test
- Timed run-to-failure (with music and software)
- Timed run-to-failure (with music alone)
- VO2 Max Test
- Timed run-to-failure (with music alone)

Random Order
Matched Pairs
Randomized
Operational Question

1-month training protocol with software and music (n=10)
1-month training protocol with music alone (n=10)
Changes in VO2 after 4-weeks of Intense Treadmill Exercise

<table>
<thead>
<tr>
<th></th>
<th>EXP 1</th>
<th>EXP 2</th>
<th>EXP 3</th>
<th>CON 1</th>
<th>CON 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VO2 (L/min)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Training</td>
<td></td>
<td></td>
<td>2.5</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Post-Training</td>
<td>2.2</td>
<td>1.8</td>
<td>3.5</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Changes in Timed Run-to-Failure after 4-weeks of Intense Treadmill Exercise

*Note that textbox over bar indicates the peak respiratory exchange ratio for the test. Notice the changes in metabolic efficiency experiences by participants post training.