A PROTOTYPE VIDEO GAME SYSTEM FOR STUDYING REHABILITATIVE LEARNING

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INTRODUCTION

Innovative human-interface devices paired with rich interactive media can enhance neuro-rehabilitation strategies aimed at enabling patients to reach essential skills for daily living. A rehabilitative gaming system could motivate users and provide an appropriate challenge level while they perform the many repetitions required for motor learning. A flexible software framework could enable the investigator to monitor and test the effectiveness of short-term drills or variable practice structures. Testing whether or not gaming and virtual reality in the context of rehabilitation are more than simply aid to repetitive practice requires the ability to deploy low-cost technology into patients' homes and clinics. Therefore, we present the initial stages of the development of an integrated system for in-home gaming for the evaluation and promotion of dexterous manipulation with the fingertips.

METHODS

Our system has three main components as shown in Figure 1. **(a)** A modified Strength-Dexterity (S-D) input device controlled by the thumb and index fingers. The previously developed S-D test challenges the user to compress an unstable spring with the fingertips. This is a difficult control task especially for patients with dexterity deficits, as the spring is prone to buckling. As a diagnostic tool, it can delineate those aging with a disability, such as osteoarthritis, and individuals with normal hand capability [1,2]. In another recent study, we have demonstrated that the S-D test shows clear engagement of different cortical-striatal-cerebellar brain networks depending on the instability of the spring [3]. Thus, one of our goals is to extend the S-D system from clinical test to dexterity training tool under the guise of a video game device. Load cells on either end of the spring are connected to a microcontroller housed in a small box. A Bluetooth module broadcasts force data to a computer running the game software. Although the device is not fully wireless, a future miniaturized version could be strapped to the wrist permitting greater freedom of movement during a gaming session. **(b)** A computer with open emulated serial ports receives and optionally filters the data streams, which drive the game mechanics. Currently Microsoft Windows and Apple Mac OS X operating systems are supported for data acquisition. And **(c)**, our work-in-progress software, the main focus of this paper, is a simple side-scrolling arcade game featuring an aircraft whose vertical position is mapped to the compression of the spring controller.

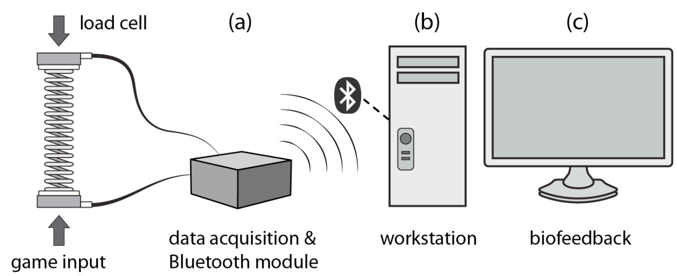

Figure 1: Schematic of the prototype game system.

We chose the Unity game design tool (Unity Technologies, San Francisco, CA) for its cross-platform coding and publishing capabilities (Windows, Mac OS X, iOS, Android), rapid prototyping features, modern 3D rendering engine, and C++ plug-in extensibility. The last feature was especially important, because a trade-off of "write-once-run-everywhere" frameworks such as Sun's Java and Mono (an open source implementation of Microsoft .NET) is that the official APIs have limited access to lower level, operating system-specific components such as serial ports and the Bluetooth stack, both of which are critical for capturing data from lab instrumentation. Writing a native C++ library and an associated wrapper class can circumvent this limitation.

The core game assets including the player's vehicle (Figure 2) and world obstacles were modeled with polygonal geometry in Autodesk Maya 2011 and then exported to the general-purpose Filmbox format (FBX). Backgrounds, textures, and other 2D elements were digitally painted in Adobe Photoshop CS5. The assets were then imported into Unity where a basic game level was assembled and scripts were attached to the interactive entities. Since Unity utilizes the Mono framework for scripting, game logic was written in C#.

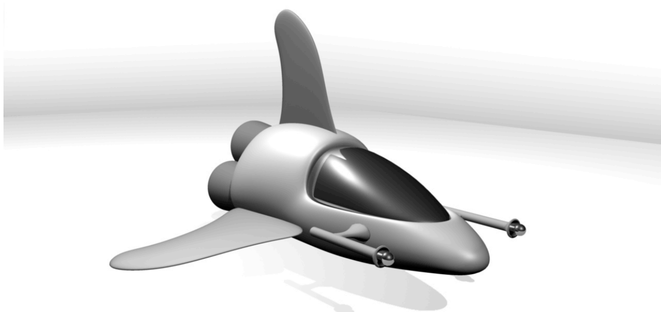

Figure 2: The player's avatar, modeled and rendered in Maya.

The structure of a standard game loop listens for user input, updates object and camera transformations, calculates collision detection, and redraws the scene with a real time lighting model. At every frame cycle the ship's vertical screen position will be set to a value proportional to the reported load cell data. The frame of reference will be ship-centric; that is, the view is locked to the ship's horizontal screen position. A combination of obstacles and parallax background traverse the screen from right to left, providing a visual cue that the ship has a velocity in the opposite direction. The user must avoid these obstacles—asteroids, buildings, or terrain depending on the level's environment—by compressing the spring at the appropriate instant and for a proper duration. Collision events will incur a small penalty for an otherwise steadily increasing score.

RESULTS AND DISCUSSION

We have demonstrated the feasibility of using a Bluetooth spring controller as a new gaming and data-gathering device for capturing the complex dynamics of dexterous finger manipulation. With only a one-dimensional force input at each sensor, the complexity of games possible is arguably limited, unless one uses a keyboard or some other device (3D load cells are expensive and heavy). Installing 3-axis accelerometers in the S-D system or using a machine vision approach like Microsoft's Kinect will greatly expand the possibilities for intuitive gestures and game control while reducing reliance on unwieldy secondary inputs or expensive force sensors.

For practical therapy, the program must provide enough challenge and variation to motivate the patient for hourly sessions over a span of weeks or months. In order to appeal to all audiences (e.g., children with cerebral palsy, elderly patients with Parkinson's or stroke), we will create several "skins" for the same game or simply a new scenario appropriate for the demographic. For example, a subject who has great difficulty controlling the spring might find the prospect of crashing his or her avatar into asteroids too discouraging. Perhaps a task better suited for that hypothetical individual would be the reverse scenario; instead of dodging obstacles, one must collect trails of energy orbs (a positive reinforcement approach) corresponding to increased control of the instability of the spring.

REFERENCES

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