A HOME-BASED MYOELECTRIC TRAINING SYSTEM FOR CHILDREN

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ABSTRACT

We present progress from an ongoing project which aims to develop a low cost home-use myoelectric training system for children. The training system is based on a first person game design within which children control a virtual limb and terminal device. Preliminary results indicate that the perceived level of control over the terminal device is high. However, designing a system which genuinely motivates and engages children remains a significant challenge.

INTRODUCTION

Children born with upper limb differences will typically reject a prosthesis unless it provides significant functional gain [1]. In the case of myoelectric prostheses a core factor which limits functional gain is control. The objective of this project is to develop a child-friendly game-based myoelectric muscle training system based on the principles of biofeedback. The system is designed for home-use and aims to be low cost. The assumption underlying our project is that myoelectric control can be implemented separately from a prosthetic device, allowing children to learn control before they are fit with a prosthesis.

It is widely recognised that patients usually fail to meet the number of movement repetitions required for behavioural change. Rehabilitation-relevant muscle activities in the context of game-play offer a motivational and engaging method to increase the amount of practise performed. Games can provide the challenging, intensive, task-specific conditions necessary to promote adaptation of behaviour [2]. In our training system players control a virtual limb with a simple terminal device. The objective in each level is to manipulate objects using a muscle decoding system based on [3]. The system does not attempt to simulate grasp but the avatar has anatomically correct dimensions and the game adheres to the principles of task-orientated gaming [4].

This work is part of an ongoing collaborative research project to co-design child prosthetics solutions [5]. As such, the work is not linear in nature. For the purpose of presentation, methods are split into two sections broadly outlining the first and second iterations of development.

METHODS

Ethics

All participants gave informed written consent. Approval was granted by the local ethics committee at Newcastle University (Ref: 17-NAZ-056).

Iteration One

Children played the game using two devices. The intact-limb controlled character movement in virtual space via a single-hand thumb stick. The virtual limb was controlled using a Shimmer3 EMG unit on the residual limb. Inertial measurement unit (IMU) data controlled the orientation of the virtual limb. Electromyography signals acquired from flexor carpi radialis (FCR) and extensor carpi radialis (ECR) controlled the virtual terminal device.

The game prototype uses a first person perspective. The core mechanics involve picking up and manipulating objects in a scene. Participants progressed through six levels. The first and second tutorial levels introduced EMG, IMU and combined EMG and IMU control. The three main levels of the game were themed around teaching a) delicate object manipulation, b) directed muscle co-contraction and c) extended manipulation of objects to reach a goal. A final optional level introduced a competing non-player character to limit the time available to complete tasks.

The system was tested on four children, two of whom had trans-radial limb deficiencies. After playing, children, and optionally their parents or guardians, answered a short questionnaire about perceived control and provided open feedback on the game in general. Feedback was also solicited from relevant domain experts.

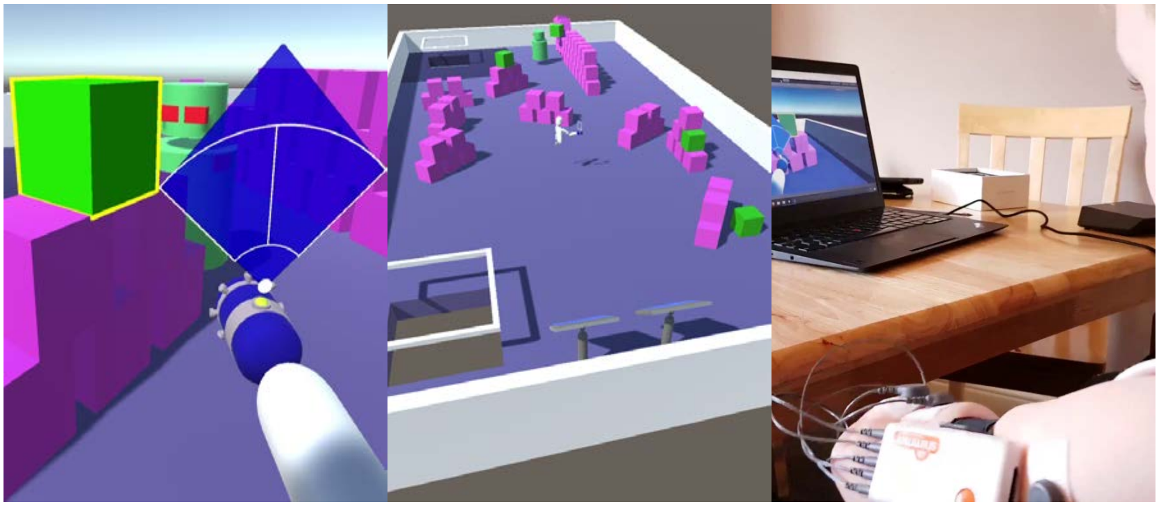

Figure 1: Iteration one. Left: play perspective showing virtual limb and biofeedback panel. Middle: a game scene, player (white) competes with non-player character (green) to collect blocks in the environment. Right: participant playing the game in a home environment.

Iteration Two

The first iteration of the game environment was built using game engine primitives. The graphics in the second version use purchased assets to provide a modern visual aesthetic, shown in Figure 2. Based on expert feedback, the game scoring systems and general time limits were updated to create a greater sense of challenge in the tasks.

The second iteration of the game uses a Delsys Quattro sensor for experimental data acquisition and trials a custom microprocessor-based controller for longer-term testing, shown in Figure 2. The microprocessor controller uses dry electrodes and performs all the signal processing necessary to send control signals to the virtual game limb. All personalised settings are retained on the device and shared with the game on connection. As EMG processing only involves linear filters, the controller side-steps sampling issues associated with low-cost EMG systems [6].

Figure 2: Images from iteration two. Left: game scene based on purchased assets. Right: microprocessor game controller, signal processing and IMU unit and two dry EMG electrodes.

RESULTS

Iteration One

Results of the perceived control questionnaire are shown in Table 1. The general rating of control for the player avatar, the virtual limb and the virtual terminal device were positive.

Table 1: Children's rating of control of game environment character.

Participant		*Rating of Control (1 poor to 5 good)*		
#	***Amputee***	***Robot***	***Arm***	***EMG***
1	Y	5	5	4
2	Y	5	5	4
3	N	4	4	3
4	N	5	4	5
Average		**4.75**	**4.5**	**4**

In general, the open feedback focussed on proposals for creating more engaging game experiences, with the majority of children providing relatively specific recommendations which would make the game better for themselves. When probed three out of four children indicated they found the tasks in each level too tedious to consider performing repetitively.

The use of gel-based snap electrodes caused a number of issues during data collection for iteration one, particularly when working with younger children. In most cases the time required to place electrodes, especially on smaller limbs caused frustration and often raised questions from parents / guardians about real world practicality.

Iteration Two

Preliminary tests for iteration two have focussed on comparisons of control systems. Development has aimed to obtain a degree of parity between the microprocessor controller and the Shimmer EMG device.

The two controllers use different EMG sensors, acquisition rates, and desktop PC interfaces, therefore comparisons have been made solely on perceived user preference. Tests were run an ad-hoc and informal basis using EMG naïve able-bodied adult participants. During tests, participants were aware of the context of the research. Participants moved virtual blocks using the game platform developed as part of iteration one and were asked for feedback as to which device they preferred.

Table 2: EMG and IMU preferences when comparing microprocessor and Shimmer controllers.

Participant	*Blocks Moved*		*Control Preference*	
#	***Microcontroller***	***Shimmer***	***EMG***	***IMU***
1	8	6	No preference	Shimmer
2	6	8	No preference	No preference
3	5	7	No preference	Shimmer

Result of recent tests are shown in Table 2. No participants expressed an EMG control preference. Two of three participants expressed a clear preference for using the Shimmer device to control the position of the virtual limb.

DISCUSSION

While children rated their overall level of control as high, perception of overall potential for engagement was subjectively low. This problem is not unique to game-based systems orientated toward children, it likely reflects a more general issue inherent to attempting to designing video games for rehabilitation purposes [2]. While the barrier of entry to creating games is now low, the skills necessary to design engaging games remain within a small group of dedicated professionals catering for larger markets. In the context of game-based rehabilitation for children, these problems of motivation and engagement are further compounded by the challenge of ensuring any behavioural activities involved are appropriately task orientated [4, 7].

Recent research questions the assumptions which typically underpin game-based training systems for prosthetics, instead proposing that transfer of learning from a virtual task to real world use only occurs when the coupling of action and perception is matched between tasks [7]. In the context of learning myocontrol, this places greater importance in replicating end-effector behaviour when reaching for, grasping and manipulating objects. How best to provide this feedback at a low cost and with relatively low complexity for younger children is unknown. Current age recommendations for virtual reality devices err on the side of caution, as such the most appropriate platform for simulating perception in adults will not necessarily be available for children in the near future.

When considering paediatric upper-limb prosthesis rejection rates [1] and the effective age ranges for rehabilitative intervention [8] it appears highly unlikely that any one game-based rehabilitation technology would be suitable for all children. A more productive approach may therefore focus on enabling the necessary hardware platforms to deliver effective child-appropriate game-based rehabilitation. As the overall market size for this type of technology remains limited, it may be prudent to consider designing for other appropriate paediatric use cases.

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