International Conference on Virtual Rehabilitation 2011
Rehab Week Zurich, ETH Zurich Science City, Switzerland, June 27 - 29, 2011

ImAble System for Upper Limb Stroke Rehabilitation

Kimberlee Jordan, Michael Sampson, Juha Hijmans
Marcus King
Industrial Research Ltd
Christchurch New Zealand
k.jordan@irl.cri.nz

Leigh Hale
Centre for Physiotherapy Research
University of Otago: Dunedin, New Zealand

***Abstract*—ImAble is an integrated upper limb (UL) exercise system comprising three devices (Able-B, Able-M and Able-X) targeting UL rehabilitation using computer games and virtual reality (VR). The system can be tailored to different levels of ability and strength, depending on the presentation of the stroke. Results from pilot testing and case studies indicate a therapeutic benefit for both movement outcome and patient motivation.**

Stroke, hemiparesis, virtual reality, rehabilitation, upper limb

I. INTRODUCTION

Six months post-stroke, 30 to 60% of stroke survivors have UL motor deficits, which can compromise activities of daily living and impair independence [1, 2]. The frequency and intensity of rehabilitation exercises are key determinants of stroke recovery [3]. Including computer games as part of the rehabilitation process provides engaging, task orientated training and can improve compliance with prescribed rehabilitation exercises [3]. There is a need for effective inexpensive UL rehabilitation devices for home use to supplement traditional rehabilitation. We have developed a low-cost system of devices, which are used in conjunction with interactive computer games and are aligned to the degree of impairment presented. This paper reports results from case and pilot studies utilizing these devices.

II. METHODS

A. The Devices

The Able-B (Fig 1a) provides near symmetrical, self-assistive bilateral arm exercise. The user sits with the arms placed on two linked and moveable arm supports at tabletop level. The hemiparetic arm is supported against gravity and makes movements in the horizontal plane which are assisted, according to the degree of weakness, by the unaffected arm. The computer games are controlled using a web camera tracking a colour patch attached to the affected hand of the user to generate the cursor at the centre of the colour patch. This system allows the hemiparetic arm and hand to be displayed on the computer screen such that it appears to interact with the computer games (Fig 1a).

The Able-M is a tabletop exerciser which provides a gravity supported unilateral rehabilitation platform, similar in concept to traditional sliding board exercise (Fig 1b). The affected arm of the user is strapped into the device and is used to control a mouse cursor on a computer screen. A range of buttons can be attached, allowing one or more fingers to be exercised while producing a mouse click (Fig 1b).

The Able-X is a light-weight handlebar 430 mm long (Fig 1c) which houses a motion sensitive game controller (CyWee Z, Taiwan) and allows movement against gravity to be carried out in a bilateral manner. The CyWee Z is similar to the Nintendo Wii controller, but interfaces with a computer. Rotation in the transverse and sagittal planes respectively produce horizontal and vertical mouse cursor translations. Mouse clicks are made by pulling the trigger of the CyWee Z with the index finger

B. The Computer Games

A suite of computer games has been developed for stroke survivors which provide a graduated series of physical challenges, from stationary target hitting, to strategic target hitting, to moving target hitting games. The games have clear, easy to see graphics, require large cursor movements in both horizontal and vertical directions, and can be adjusted over a broad range of skill levels

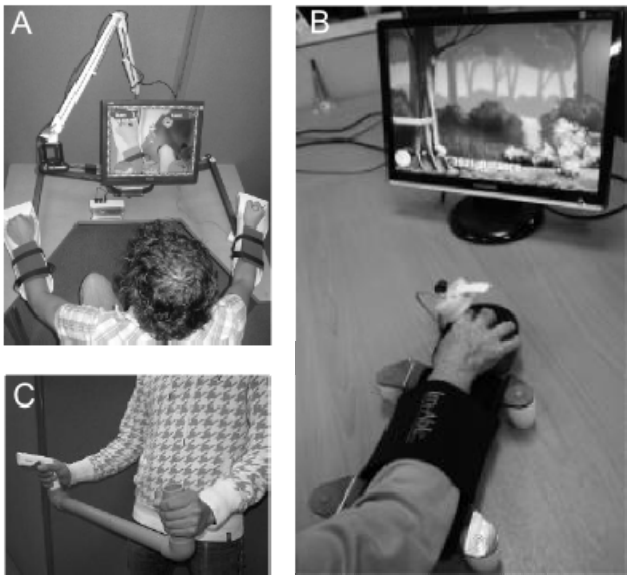

Figure 1. a) Able-B with web camera game; b) Able-M with computer game; c) Able-X (CyWee Z fitted into bilateral handlebar).

This project was funded by the Foundation for Research Science and Technology, NZ.

978-1-61284-474-9/11/$26.00 ©2011 IEEE

C. *Participants*

In the Able-B case study, 5 post-stroke participants with UL hemiparesis were recruited. The mean age of the participants was 61.8 years (range 45 – 76 years). The mean time post stroke that the intervention was started was 45.2 weeks (range 9 – 64 weeks). In the Able-M case study, 3 post-stroke participants with UL hemiparesis were recruited. The mean age of the participants was 45.4 years (range 30 - 56 years), all participants were 6 months post stroke. In the Able-X pilot study, 14 post-stroke participants with UL hemiparesis were recruited. The mean age of the participants was 71 years (range 47-85). Time since stroke was 1 - 6 years.

D. *Assessment, intervention and outcome measures*

All participants signed informed consent and the Able-B and Able-M studies were approved by the NZ Health and Disabilities, Upper South A, Regional Ethic Committee, while the Able-X study was approved by the University of Otago, NZ Human Ethics Committee. For the Able-B case study, a base line assessment occurred in the week prior to the start of intervention (T0), participants completed a 6 week intervention consisting of supervised, 45 minute sessions, 4x/week and a second assessment occurred one week post intervention (T1). For the Able-M case study, the initial assessment occurred after enrolment in the study (T0). Following a 4 week period where no interventions were supplied, participants were re-assessed (T1). Participants completed a 4 week intervention consisting of supervised, 45 minute session 3x/week and were re-assessed at the end of the intervention (T2). For the Able-X pilot study, an initial assessment occurred after enrolment in the study (T0). Following a 2.5 week sham-intervention period where participants played mouse based computer games using their unaffected arm, participants were re-assessed (T1). After a 2.5 week period of no intervention, participants were again re-assessed (T2). Finally a 2.5 weeks intervention consisting of 8-10 supervised 45-60 minute sessions was completed followed by a final assessment (T3). For all studies, the Fugl-Meyer upper limb motor function test (FMA-UL) was the primary outcome measure. For the Able-B trial, participant motivation was also assessed using the Intrinsic Motivation Inventory after the intervention.

III. RESULTS

For the Able-B case study, the FMA-UL score increase ranged from 1 to 5 points after 6 weeks of therapy (Fig 2a).

Table 1. Intrinsic Motivation Inventory results for the Able-B case study.

Participant	IMI Total	Interest/ Enjoyment	Perceived competence	Effort/ Importance	Perceived choice	Value/ Usefulness
1	84%	59%	74%	97%	94%	100%
2	95%	100%	76%	100%	100%	98%
3	89%	96%	71%	86%	100%	90%
4	801%	94%	83%	83%	76%	65%
5	92%	94%	83%	89%	96%	96%

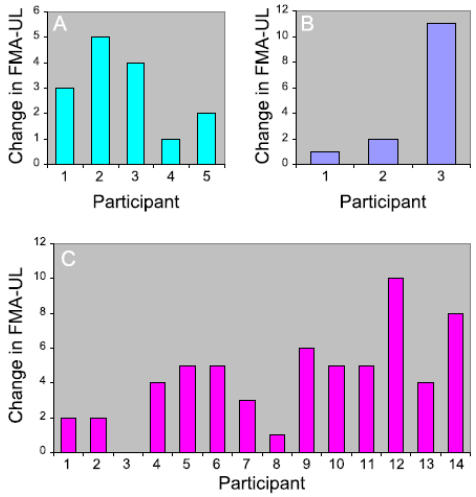

Figure 2 Change in the Fugl-Meyer Upper Limb Assessment (FMA-UL) for a) the Able-B; b) the Able-M and c) the Able-X interventions.

The results of the IMI ranged from 80 to 95%, indicating that all participants were well motivated to comply with the Able-B therapy (Table 1). For the Able-M case study the FMA-UL score increase ranged from 1 to 11 points after 4 weeks of therapy (Fig 2b). For the Able-X pilot study, the mean improvement as an effect of the intervention was 4.2 (T2 to T3) (Fig 2c). Focus groups and personal interviews held after the intervention show participants both enjoyed the experience and reported perceived gains in UL movement, concentration and balance

IV. CONCLUSIONS

The results demonstrate that the ImAble system has the potential to improve UL function in a stroke population and highly motivates the user to exercise. Improvements in UL function were observed during case or pilot studies of three devices designed to provide augmented physical therapy for people with UL disabilities. The system provides a range of exercises which can be selected to suit the physical and cognitive abilities of a patient ranging from severe hemiparesis to almost able-bodied or integrated as a systems approach to UL rehabilitation. Overall these studies suggest that further research on a larger sample size and range of stroke survivors with UL hemiparesis is warranted to provide a greater level of clinical evidence as to the effect of the ImAble system for people with UL hemiparesis.

REFERENCES

[1] G. Kwakkel, B. J. Kollen, and R. C. Wagenaar, "Therapy impact on functional recovery in stroke rehabilitation: a critical review of the literature," Physiotherapy, vol. 13, pp. 457-470, 1999.

[2] J. Whitall, S. McCombe Waller, K. H. Silver, and R. F. Macko, "Repetitive bilateral arm training with rhythmic auditory cueing improves motor function in chronic hemiparetic stroke," Stroke, vol. 31, pp. 2390-2395, 2000.

[3] G. Kwakkel, B. J. Kollen, and H. I. Krebs, "Effects of robot-assisted therapy on upper limb recovery after stroke: A systematic review," Neurorehabil Neural Repair, vol. 22, pp. 1-11, 2007.