Kinecting the Moves: The kinematic potential of rehabilitation-specific gaming to inform treatment for hemiplegia

S M N Glegg[1], C T Hung[2], B A Valdés[3], B D G Kim[4], H F M Van der Loos[5]

[1]Therapy Department, Sunny Hill Health Centre for Children,
3644 Slocan Street, Vancouver, B.C., CANADA

[2,3,4,5]Department of Mechanical Engineering, University of British Columbia,
6250 Applied Science Lane, Vancouver, B.C. V6T 1Z4 CANADA

[1]sglegg@cw.bc.ca, [2]tina.ct.hung@alumni.ubc.ca, [3]bulmaro.valdes@alumni.ubc.ca,
[4]brandonkim.bk@alumni.ubc.ca, [5]vdl@mech.ubc.ca

[1,2,3,4,5]*http://caris.mech.ubc.ca/feathers/*

ABSTRACT

Two therapy applications for hemiplegic arm rehabilitation were developed and tested, along with a motion tracking application that used two interfaces (PlayStation® Move and Microsoft® Kinect™) for videogame play through a social media application developed on Facebook©. To promote affected arm use, users are required to employ bimanual symmetrical hand motions. Preliminary kinematic data analysis of two subjects obtained during user testing is presented. Clinically relevant information, such as range of motion, trunk compensation, and total distance of hand movement was extracted from kinematic data. Results showed the system is capable of accommodating users with large variation in arm function.

1. INTRODUCTION

The use of commercial gaming systems is gaining momentum in the field of rehabilitation (Galvin and Levac, 2011). These systems have been applied to target physical rehabilitation goals including upper extremity function (Luna-Oliva et al, 2013). Challenges exist, however, in the application of these systems to meet the therapeutic needs and physical capacity of different patient populations. Therapeutic gaming may be one treatment tool selected by therapists for individuals with hemiplegia as a means of providing opportunities for repetitive motor practice that targets specific movement patterns and encourages the use of the impaired limb (Orihuela-Espina et al, 2013). Accordingly, the development of novel game applications and user interfaces for these commercial systems is expanding the potential for the technology to be integrated in this way.

The purposes of this paper are to describe the development of two commercial interfaces (PlayStation Move and Microsoft Kinect) that were adapted to promote bilateral arm use during social media-based game play, and to share preliminary kinematic data of two subjects with hemiplegia using the systems. The analysis of kinematic data offered by the systems allows for the extraction of clinically relevant information that can be shared with patients' therapists for further interpretation. Both PlayStation and Kinect systems are capable of determining the total distance moved in a session, range of motion (ROM) of the user, and hand offsets for different directional movements. Moreover, the Kinect system is capable of determining excessive trunk movements.

2. METHOD

2.1 System Description

In order to use the two motion capture interfaces, a computer application (FEATHERS Motion) was developed for the upper limb rehabilitation of hemiparetic users. Another application, FEATHERS Play on Facebook, enabled users to connect with their therapists and other participants, to receive recommendations about games, and to review their game scores. An alternate version of the application was developed for therapists to monitor users' game scores and facilitate communication with their patients. Both applications were refined based on the results of previous usability testing conducted with rehabilitation professionals (see Valdés et al., 2014 for more details).

The FEATHERS Motion application relies on the use of bimanual motions in the frontal plane to control the mouse cursor on a Windows® 7 personal computer. Two motion modes (Visual Symmetry and Point Mirror Symmetry) are available for mapping the hand with the least movement into cursor motion. In the Visual Symmetry mode, users are required to move both hands at the same time in the same direction. In the Point Mirror Symmetry Mode, users must move both hands around the circumference of a circle, similar to steering a wheel.

2.2 Participants

Participants were two male adolescents recruited through therapists at a local rehabilitation centre. Subject 1 (19 years old) was right-hand dominant and presented with left hemiparesis with increased finger flexor tone post-traumatic brain injury and brachial plexus injury two years prior. Some decreases in both active and passive ROM for shoulder flexion, extension and external rotation persist. He was also observed to compensate with his flexors during shoulder abductions. Subject 2 (13 years old) was left-hand dominant prior to incurring a stroke 14 months ago. He presented with right hemiparesis, with weakness of the external rotators of the shoulder, no active supination of the forearm and decreased wrist flexor and extensor strength. A healthy right-handed male control (28 years old) participated as a comparison.

2.3 Procedure

Each user test session included a moderator, note taker, caregiver/guardian and therapist. All sessions were audio and video recorded. University of British Columbia Ethics Board approval was obtained, along with informed consent from participants and a parent/guardian. Each user participated in a 90-minute session during which a set of tasks was completed to evaluate ease of use of the system. Users were introduced to the FEATHERS applications and the interfaces, and played “Lucky Pirate” (OUAT Entertainment) in both motion modes after receiving instructions on the movement and task requirements. Kinematic data was recorded for both interfaces, i.e., the 3D position of the PlayStation Move controllers and of all upper limb joints using Microsoft Kinect.

3. RESULTS & DISCUSSIONS

3.1 Performance Data for One Session

Joint position data were analyzed for 2.5-3 minutes per subject using six joints (wrists, shoulders, shoulder centre, and hip centre) during the Visual Symmetry play mode. Recommended filter values provided by Kinect for Windows SDK were applied to minimize jittering and to stabilize joint positions over time.

3.1.1 Total Distance Travelled in 2D. The total distance travelled by the wrists (Table 1) was calculated by subtracting the wrists’ horizontal (x-axis) and vertical (y-axis) positions from consecutive camera frames and summing the absolute values of the differences through the whole duration of the interaction. Because most of the wrists’ movements occurred in the frontal plane, only the horizontal and vertical positions were used for this calculation. In the next study phase where users are required to perform movements with larger variation in depth (z-axis), 3D data of the wrists will be used.

Subject 2, who had the greatest level of impairment, appeared to cover more distance than the other two subjects. Video and kinematic data analyses suggest that this might be related to his frequent need to rest his hands in his lap between movements. This effect can be observed in the large values for both vertical distances. Subject 2 was observed to employ compensatory movements of the trunk to accommodate for his limited upper limb motor control. Overall, the values for Subject 1 were closer to the healthy control’s results. This finding may relate to the shorter and more direct trajectories between targets compared to those of Subject 2. This observation may be explained by Subject 1’s greater motor ability and the fact that he kept his arms at chest level for most of the interaction.

Table 1. *Total Distance Travelled (* denotes hemiparetic side)*

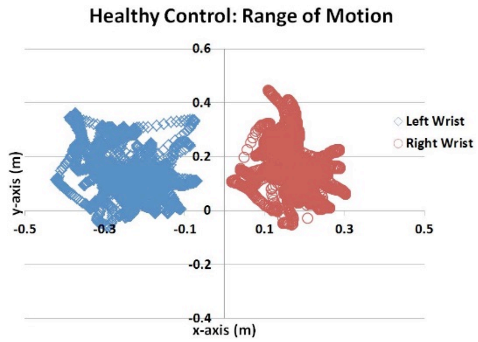
	Horizontal (m)		**Vertical (m)**	
	Left Hand	**Right Hand**	**Left Hand**	**Right Hand**
Control	4.94	4.11	6.99	7.35
Subject 1	7.04*	6.07	8.22*	6.69
Subject 2	8.32	9.11*	13.85	7.64*

Therapists may find information about the total distance travelled useful, in conjunction with the straightness of the hands’ trajectories, in order to assess if the users’ movements are progressing towards healthy movement patterns. Distance travelled may have potential as an indicator of the recovery progress of participants.

3.1.2 Range of motion. Table 2 shows the ROM of each hand, computed based on the wrist movements of each subject (Figures 1-3). All figures were centred with respect to the median values of the hip centre. In the vertical direction for both hemiparetic subjects, and in the horizontal direction for Subject 1, larger ROM of the non-paretic versus the paretic arm was recorded. These findings are consistent with clinical presentation during functional tasks. Dissimilar findings for Subject 2 in the horizontal plane may be explained clinically by his limited control of the paretic side and his tendency to use compensatory trunk movements during play. The magnitudes of difference should be interpreted with caution owing to indeterminate tracking error of the system.

Table 2. *Range of Motion (* denotes hemiparetic side)*

	Horizontal (m)		Vertical (m)	
	Left Hand	Right Hand	Left Hand	Right Hand
Control	0.34	0.28	0.41	0.49
Subject 1	0.40*	0.58	0.40*	0.56
Subject 2	0.45	0.49*	0.60	0.50*



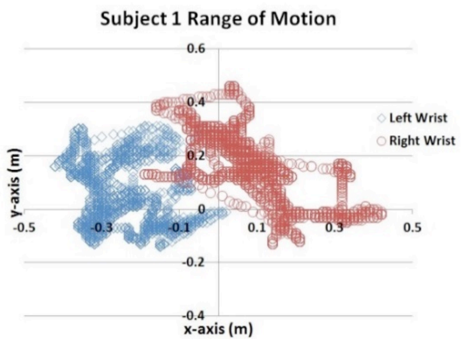


Figure 1. *Healthy control wrist range of motion.* **Figure 2.** *Subject 1 wrist range of motion.*

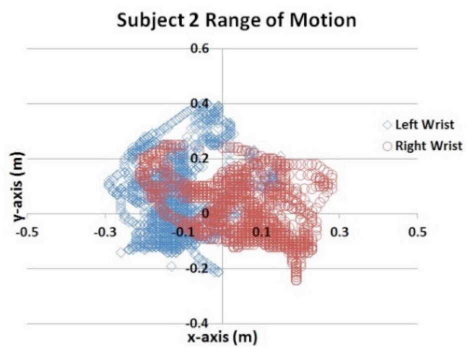


Figure 3. *Subject 2 wrist range of motion.*

3.2 Data Analysis on Directional Movement

In order to extract kinematic information related to the subjects' intended direction of motion, all movements in a game session were categorized into horizontal and vertical segments. This section presents data on the upward movement that shows subjects' trunk compensation and vertical hand offsets.

3.2.1 Trunk Compensation. Figures 4 and 5 show one upward movement trajectory for each subject. The paretic side of both subjects moved in a longer trajectory that was less straight than the unaffected side. In addition, subjects tried to synchronize both of their arms to perform a bimanual movement, evidenced by both hands stopping close to the same height. Wrist and shoulder trajectory for Subject 2 showed clear evidence of excessive trunk movement on the right side. Further 3D kinematic analysis indicated that his left shoulder moved downwards to the left and backwards, while his right shoulder moved upwards to the left and forward. No excessive trunk movement was observed in Subject 1's trajectory.

3.2.2 Vertical offsets of both hands in an upward movement. Three upward movement data sets on vertical offsets for each subject were plotted in Figure 6. Values were calculated with respect to the paretic side (i.e. a positive value means the non-paretic side was at a higher vertical position). The vertical wrist offset of Subject 1 ranged from a value close to 0 m to 0.28 m, while for Subject 2, it ranged from -0.04 m to 0.09m. Moreover, all

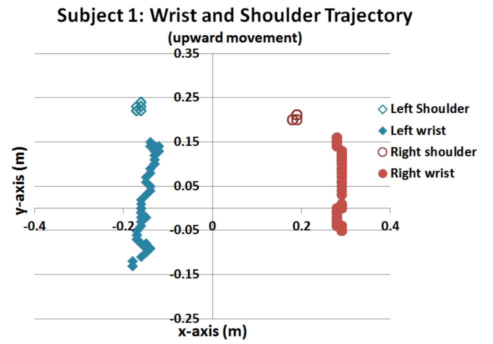


Figure 4. *Subject 1 wrist and shoulder trajectory.*

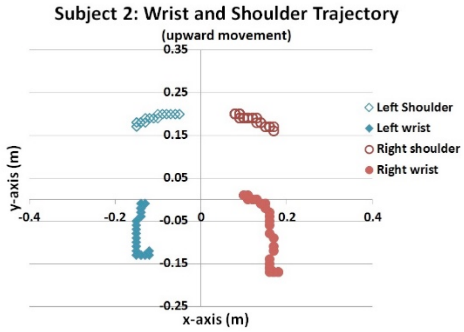


Figure 5. *Subject 2 wrist and shoulder trajectory.*

offsets shared a similar decreasing trend with respect to motion time. This result is consistent with the discussion in Section 3.2.1, which suggests that the subjects were trying to reach the same vertical position at the end of the motion.

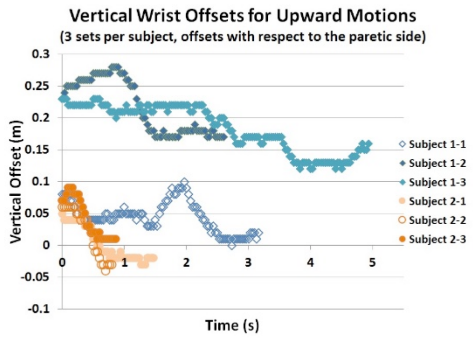


Figure 6. *Vertical wrist offsets for upward movements.*

4. CONCLUSIONS AND FUTURE WORK

Kinematic analysis of data provided by commercially available motion tracking technology could serve as an additional rehabilitation tool for therapists. While system limitations exist relative to the accuracy of gold standard motion tracking technology, this trend data can be used in tandem with clinical observations to identify variations in subjects' gross motor movements compared to healthy controls. This study demonstrates the type of data that could be provided to therapists about the quality and amount of movement during therapeutic gaming. These results will inform the next design iteration of this project to evaluate the effectiveness of a 6-month home-based treatment using the system.

Acknowledgements: We would like to acknowledge the FEATHERS team, the staff from Sunny Hill Health Centre for Children, Reality Controls Inc., Brendan Sexton, and the participants and their families.

5. REFERENCES

Galvin, J, and Levac, D, (2011), Facilitating clinical decision-making about the use of virtual reality within paediatric motor rehabilitation: Describing and classifying virtual reality systems, *Dev Neurorehabil,* **14**, *2*, pp. 112-122.

Luna-Oliva, L, Ortiz-Guitierrez, R, Martiniz, PR, Alquacil-Diego, I, Sanchez-Camarero, C, and del Carmen, M, (2013), Kinect Xbox 360 as a therapeutic modality for children with cerebral palsy in a school environment: A preliminary study, *NeuroRehabil,* **33**, *4*, pp. 513-521.

Orihuela-Espina, F, Fernandez del Castillo, I, Palafox, L, Pasaye, E, Sanchez-Villavicencio, I, and Leder, R, (2013), Neural reorganization accompanying upper limb motor rehabilitation from stroke with virtual reality-based gesture therapy, *Topics in Stroke Rehabil,* **20**, *3,* pp. 197.

Valdés, BA, Hilderman, CGE, Hung, CT, Shirzad, N, Van Der Loos, HFM, (2014), Usability testing of gaming and social media applications for stroke and cerebral palsy upper limb rehabilitation. *Proc. IEEE Eng. Med. Biol. Soc.,* Chicago*, In Press*.