Low-cost active video game console development for dynamic postural control training

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ABSTRACT

Weight shifting is a key ability to train and monitor in rehabilitation processes. In the last decade, active video game console (AVGC) has been viewed as a promising and appealing way to solicitate weight shifting ability. However, to date, no commercially available AVGC was specifically developed for balance and postural control throughout rehabilitation processes. The present study aims to establish a proof of concept about the possibility to integrate, in a unique AVGC, a board, monitoring the player centre of pressure and a Kinect, which take into account the postural movement and the player motor function capacity.

1. INTRODUCTION

Dynamic balance is particularly relevant in rehabilitation because of its importance in daily life activities (Brouwer et al, 1998). The ability to initiate and control weight shifts have been reported as a prerequisite for independent walking in various populations with motor disability (Eng and Chu, 2002). Performing weight shifting in response to a visual stimulus is a key ability to train and monitor in many motor impaired individuals (Dault et al, 2003; Laufer et al, 2000). More specifically, visually guided weight shifting is often required in everyday life situations. However, most tests currently used by clinicians and researchers involve self-generated weight shifting in which a person is asked to shift his or her weight within his or her stability limits (de Haart et al, 2005) and does not require responding to a visual stimulus.

The lack of evidence concerning visually guided weight shifting ability could be related to the difficulty to adequately evaluate and train this complex ability. Active video game consoles (AVGC) have been used in people with motor impairment to solicit M/L weight shifting in the context of visually guided and task-oriented movements (Snider et al, 2010). AVGC based on centre of pressure (CoP) displacement measurement could therefore be viewed as a promising and appealing way to induce such movements. Ballaz et al. (2014), evaluated the postural movement during a Nintendo Wii™ game (Nintendo, Kyoto, Japan) in children with cerebral palsy. They reported inappropriate trunk movements when participants with cerebral palsy shifted their weight from one leg to the other. This result highlighted the limit of this game controller, based on CoP displacement, to solicit adequate M/L weight shifting. Indeed, it is known that optimal weight shifting should be mainly performed with minimal trunk inclination (Michalski et al, 2012). Therefore, a video based controller should be added to take into account postural movements of the participants. Also, base of support width affects weight shifting and can vary greatly between participants, especially in a rehabilitation context. It is therefore crucial to consider this parameter to make sure that game requirements are adapted to the participant's weight shifting capacity.

In the next few years, we intend to develop and validate an AVGC dedicated to dynamic postural control rehabilitation. A first version of the AVG is proposed. The aim of the present study is to establish a proof of concept using different low-cost technologies to develop an innovative AVGC, which take into account the player weight transfer performance and the player postural movement. More specifically, this present study provides preliminary results on 1) trunk inclination and 2) base of support width measured using a video controller.

2. METHODS

An AVGC was developed combining the Nintendo Wii Fit board (Nintendo, USA) and the Kinect (Microsoft, Redmond, Washington, USA), to solicit M/L weight shifting in response to visual stimuli in a functional context. The association of the Wii Fit board and the Kinect allows quantifying both the CoP displacement (Bartlett et al, 2014) and the postural strategy (Clark et al, 2012) used by the player. The goal of the game is to catch water drops with a bowl that the player controls by moving laterally his CoP (i.e. performing M/L weight shifting). The Kinect provides the opportunity: (1) to quantify the weight shifting strategy used by the player and (2) to provide a visual feedback about the adopted posture. More specifically, when the player shifts his weight with an excessive lateral trunk bending, the bowl topples (see Figure 1). Based on previous work (Ballaz et al, 2014) the trunk inclination required to make the bowl topple was set at a 20° angle. The amplitude of weight shifting and the velocity of the water drops are adjustable depending on the functional level of the player.

Figure 1. *The visual feedback of trunk movement in the developed active video game.*

2.1 Participants

A convenience sample of 4 healthy adults aged between 24 and 38 years old (2 males and 2 females; mean age [SD]: 30.5 [6.8] years; body mass: 65.3 [14.0] kg; height: 175 [9] cm) were recruited from our research center. A child of 6 years old with cerebral palsy (CP) was also recruited to test the AVGC (Gross Motor Function Classification System level I; body mass: 24 kg; height: 117.3 cm).

2.2 Procedure

2.2.1 Evaluation of the Kinect system. Healthy participants were asked to stand on the Wii Fit board at a distance of 2.7 meter from the Kinect. They were asked to place their feet following verbal instructions given by the examiner and to keep the same feet placement during a 5 seconds period. Participants were asked to simultaneously place their right and left foot as follow: left side, middle and right side. By combining the left and right foot positions, a total of 9 positions were tested. Thereafter, the participants were asked to shift their weight by bending the trunk laterally. They had to complete a set of 10 weight shifting at different amplitude, i.e. small, medium and maximal amplitude. This procedure was implemented to report the parameters using the usual game configuration.

2.2.2 Evaluation of the AVGC. A child with CP was asked to play the game as described above, namely “Choplo”, during 5 minutes. The game parameters were defined as follow: Maximal tolerated trunk inclination: 20 degrees; water drop fall frequency: 0.3 Hz; maximal horizontally water drop distance, 20 cm (relate to the ankle distance). Here, we wanted to test the performance of this integrated multi-sensors system. No measurement was performed with this participant.

2.3 Measurements

For all tests, the data were recorded synchronously by the Kinect and a 12-camera motion analysis system (ViconMX, Oxford Metrics, Oxford, UK) cadenced at 100 Hz. Reflective markers, placed over several anatomic landmarks according to a slightly modified full body plug-in gait kinematic model, were tracked (see Ballaz et al, 2014 for details). Kinematic data were exported from the Vicon workstation software and subsequently analysed using MatLab 7.4 (The MathWorks Inc., USA). The Kinect data were recorded and analysed with Microsoft NUI library (Microsoft, Redmond, USA). Microsoft’s ‘Kinect for Windows SDK’, was used to provide an Application Programmer’s Interface (API) to the Kinect hardware. The API was used to interface with the Kinect sensor and its skeletal tracking software providing an estimate for the position of 20 anatomical landmarks at a frequency of 30 Hz. To characterize the trunk inclination during M/L weight shifting, the trunk was modeled as a one-segment rigid linked system. The trunk segment was defined by the C7 marker and the middle of the posterior pelvic markers. With the Kinect, the trunk inclination was defined as the angle between the spine and the shoulder center markers (as defined by the Kinect kinematic model) versus the world vertical axis. To quantify the foot position and thereby the base support width, the ankle joint centre position was estimated by averaging the position of the internal and external malleolus Vicon markers. The ankle distance measured by the Kinect was calculated based on the ankle joint center marker.

2.4 Statistics

Pearson correlation coefficients were calculated to quantify the relationship between the Kinect and the motion analysis measurement for the distance between the ankle and the trunk inclination angle. Individual correlation was assessed for the two variables on all four participants.

3. RESULTS

The trunk inclination angle measured with Kinect and the motion analysis system highly correlate ($r = 0.96$; $p<0.05$). Individually, the correlations were similar ($r = 0.97$; $r =0.98$; $r =0.97$ and $r =0.97$ for participants 1, 2, 3 and 4 respectively) with a $p<0.001$ for all correlations. No correlation was found between trunk angular velocity and measurement differences between the two systems.

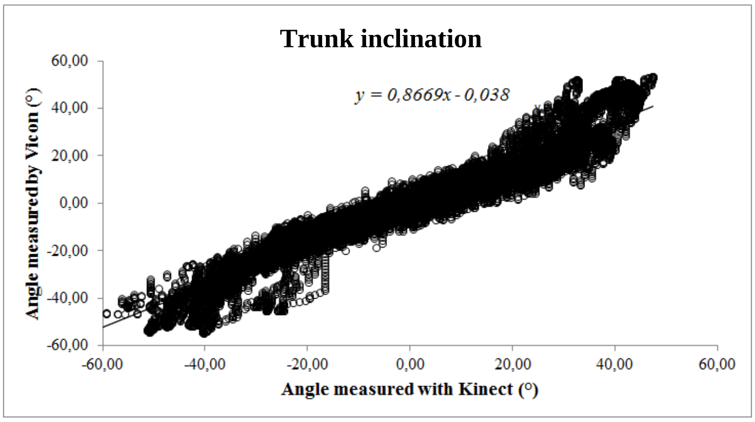

Figure 2. *Pearson correlation for the trunk inclination angle measured with Kinect and motion analysis system.*

A good correlation ($r = 0.85$; $p<0.05$) was observed between the ankle distance measured with Kinect and with motion analysis system. Individually, correlations were high ($r =0.86$; $r =0.85$; $r =0.88$ and $r =0.98$, $p<0.05$).

The child with CP who played the AVG verbally reported that the game was a little difficult. The child reported that the water drops were falling too far on each side to be able to catch them and that they were falling too fast.

4. DISCUSSION

This study presents a new AVGC combining the Wii Fit board and the Kinect to solicit M/L weight shifting in response to visual stimuli in a functional context. The AVGC use the CoP measured by the Wii Fit board as a controller to move the bowl from one side to the other. Plus, the Kinect allows the quantification of trunk movement during M/L weight shifting. To our knowledge this is the first active video game combining these two devices.

The lateral trunk inclination was measured using a Kinect. Our results showed a high association between the motion analysis system and the Kinect measurements. The trunk inclination threshold was fixed based on previous results comparing strategy of M/L weight shifting in children with CP and typically developing children (Ballaz et al, 2014). Our data demonstrated a high correlation in a range of 40 degrees of trunk inclination. Our results supports the results from Clark et al, (2012) who compared the maximal trunk inclination measured with the Kinect and an optoelectronic motion capture system during functional reach test.

The experiment with the CP participant showed the ability of this integrated multi-sensors system to function in gaming context. The child with CP reported that the water drops were too far on the sides and that this parameter increased the difficulty of the game. It is important to note that the game was not calibrated to take into account the participant base of support width. As mentioned previously, the width of the participant's base of support can greatly vary in a rehabilitation context. Furthermore, weight shifting amplitude is related to the base of support width, a larger base of support allows a greater weight shifting amplitude. The participant's feedback highlights the importance to take in account the base of support width in the game setting. The high correlation reported in the present study between the ankle positions defined with the Kinect and the ankle positions defined with the optoelectronic motion capture system, let us consider that the Kinect is an efficient tool to quantify base of support width. Further studies are required to confirm this point and also to establish a relation between ankle distance and base of support width. Indeed, depending on the foot shape, the ankle position does not exactly represent the limit of the base of support. Eventually, it would be pertinent to calculate the base of support width continually while participants play on the AVGC, because foot movements are expected during the game. On the other hand, our results should be taken precociously, the correlation coefficient do not allow quantifying systematic bias with Kinect measurement. Further analysis should be performed to answer those limitations.

Further research should validate the estimation of distance between the ankles in children with CP. They often have foot deformities and joint contractures in the lower limbs that may compromise the estimation of ankle distance by the Kinect.

Moreover, the child with CP reported, after playing at the game, that the water drop falls were too fast. The game was developed to alter the velocity of the water drops depending on the functional level of the player. This result put in perspective that further studies should be performed to define the optimal velocity of water drops to adapt the game for people with impaired motor function.

5. CONCLUSION

An active video game combining the Wii Fit board and the Kinect is a promising way to assess visually guided weight shifting ability. This project also demonstrated that the Kinect is an effective tool to measure the distance between the ankle and the trunk inclination.

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