Is the Nintendo Wii Suitable for Stroke Rehabilitation? A Pilot Feasibility and Usability Study

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Key words: Video games, stroke rehabilitation, upper extremity, virtual reality.

Abstract

Background: Individuals with stroke experience various physical and cognitive deficits, which impact their everyday function. The Nintendo Wii videogame console (Wii) is an emergent, low-cost virtual reality system that entails the use of active movement, and therefore may be beneficial as a tool for stroke rehabilitation. **Purpose**: 1) To assess the feasibility and usability of the Wii with participants with subacute (inpatients) and chronic stroke (outpatients); 2) to characterize participants' experience of using the Wii; and 3) to objectively measure the amount and intensity of movement elicited during the Wii experience. **Methods:** Fourteen participants (mean age 56 years; eight outpatients and six inpatients) experienced three games while wearing accelerometers on both wrists: Wii-Sports Bowling, Wii-Fit Ski-Slalom, and Wii-Sports Tennis. Participants completed questionnaires providing feedback regarding their experience, perceived exertion and system usability. Game performance was documented and accelerometer readings objectively quantified the activity kilocounts per hand for each game. **Results:** Participants from both groups positively experienced the Wii while perceiving low exertion. Usability scores were high with non-significant differences between groups. However, outpatients performed significantly better playing all games. Tennis elicited

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more upper extremity activity kilo counts and vigorous movement than Bowling and Ski. **Conclusion:** The Wii has potential to be used for stroke rehabilitation by participants with subacute and chronic stroke. Different games elicit varying amount and intensity of movement of both hands. This information can assist the occupational therapist plan therapeutic goals when using the Wii in stroke rehabilitation.

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Background and Purpose

Individuals who sustain a stroke commonly experience residual motor deficits of the upper extremity (UE), which can affect everyday function (Nakayama, Jorgensen, Raaschou, & Olsen, 1994). Evidence suggests that simple repetitive movements of the affected UE do not improve its functional ability (French et al., 2010), nor does it facilitate the reorganization process of the brain (Plautz, Milliken, & Nudo, 2000). However, the incorporation of the UE into meaningful, task-oriented activities does contribute to reorganization (Jang et al., 2003). As a result, many resources have been devoted to developing effective therapeutic modalities to advance functional recovery of the UE (Oujamaa, Relave, Froger, Mottet, & Pelissier, 2009).

A relatively novel approach is the use of virtual reality (VR), which refers to a computer-generated environment that clients can interact with and perceive similar to the real world (Henderson, Korner-Bitensky, & Levin, 2007; Jang et al., 2005; Lucca, 2009; Mumford & Wilson, 2009; Piron et al., 2009; Schultheis & Rizzo, 2001). It is suggested that VR therapy provides an engaging medium in which purposeful tasks may be easily graded and controlled and therefore may improve motor function poststroke (Henderson et al., 2007; Jang et al., 2005; Lucca, 2009; Mumford & Wilson, 2009; Piron et al., 2009; Rand, Katz, & Weiss, 2009; Schultheis & Rizzo, 2001; Yavuzer, Senel, Atay, & Stam, 2008). However, the prohibitive cost, lack of commercial availability, and the technical skills required to operate a VR system limits its utility in a clinical environment (Deutsch, Borbely, Filler, Huhn, & Guarrera-Bowlby, 2008).

Recently, the use of low-cost videogame consoles has been examined to address the limitations associated with early VR systems. The increase in availability of low-cost VR systems such as the Sony PlayStation 2 EyeToy (EyeToy) and the Nintendo Wii (Wii) seems to make these home-based systems ideal for application with various populations. Practitioners suggest they approximate the benefits associated with VR and have potential for use in rehabilitation (Deutsch et al., 2008).

Recently three feasibility studies have been published using the Wii to improve the weak upper extremity of individuals with stroke during the subacute-chronic stages poststroke (Mouawad, Doust, Max, & McNulty, 2011; Saposnik et al., 2010; Yong Joo et al., 2010). No adverse effects (such as fatigue, dizziness, seizures, spasticity and pain) were reported and improvement of the weak upper extremity was found (Mouawad, 2011; Saposnik et al., 2010; Yong Joo et al., 2010). The potential of the Wii has also been explored with individuals with cerebral palsy (Deutsch et al., 2008) and in the elderly as a means of increasing social interactions, quality of life, and confidence in the ability to prevent falls (Bell et al., 2011; Labbe, Levesque, & Sturdivant, 2009).

Researchers have explored the characteristics of videogames that may aid in stroke rehabilitation (Burke, McNeill, Charles, & Morrow, 2009) and have established user preferences among various populations (Flynn, Lange, Yeh, & Rizzo, 2008). The results suggest videogame systems may be advantageous, with reported high levels of enjoyment and ease of use amongst healthy participants and participants with various disabilities. In addition, these systems may increase rehabilitation adherence (Bell et al., 2011; Ramchandani, Carroll, Buenaventura, Douglas, & Liu, 2008), as it has the potential to be an effective motivating factor.

Despite these positive prospects, the use of the Wii in stroke rehabilitation has not been studied in a systematic manner. Therefore, we decided to conduct this pilot study which aimed to: 1) assess the feasibility and usability of the Wii with individuals with subacute (inpatients) and chronic stroke (outpatients), 2) characterize participants' experience of using the Wii in stroke rehabilitation, and 3) objectively measure the amount and intensity of UE movement elicited during the Wii experience. Since occupational therapists often treat the upper extremity of individuals as one of the ways to facilitate independence in daily living, the Wii can potentially be used as an adjunct tool to traditional therapy. This information can assist occupational therapists in deciding if the Wii is suitable to be used as an intervention tool for their client.

Methods

Participants

This study was advertised in two rehabilitation centers. Inclusion criteria included sustaining a stroke 2-12 months prior to the study and being able to understand the questionnaires. Participants who were medically unstable, had a history of seizures or epileptic condition, had a neurological condition other than stroke, or did not have full UE function prior to the stroke were excluded from the study. Ethical approval was provided by the Clinical Research Ethics Board of the University of British Columbia and written consent was obtained from all participants.

Materials

The Nintendo Wii - games and setup:

The Nintendo Wii videogame console (http://www.nintendo.com/wii) was used, with Wii Sports Bowling (Bowling), Wii Sports Tennis (Tennis), and Wii Fit Ski-Slalom (Ski) being the specific games utilized. Each game simulates the sport for which it is named (Appendix A). The experience was projected by an overhead projector, on a screen 55 inches wide by 55 inches high. An armless chair was used by all participants during Bowling and Tennis, and for participants who needed to sit for Ski.

The Wii Experience:

The Short-Feedback Questionnaire-Modified (SFQ-M; Kizony, Katz, Rand, & Weiss, 2006) consists of 10 items that assess the sense of presence, desire to repeat the experience, ability to implement the game at home, and discomfort and difficulty during each experience. The first six items examined the participants' presence and were developed as an abbreviated version of the Presence Questionnaire (PQ; Witmer & Singer, 1998). Most of the items are scored on a scale of 1 (not at all) to 5 (a lot). This questionnaire has been used in other feasibility studies with healthy individuals and individuals with stroke (Rand, Kizony, & Weiss, 2008).

The Borg Scale of Perceived Exertion (Borg, 1990; 1998) was utilized to assess the participants' perceived physical exertion while playing the various games. This scale ranges from 6 (no exertion) to 20 (maximal exertion).

The System Usability Scale (SUS; Brooke, 1995) was used to assess the usability of the Nintendo Wii. The questionnaire consists of 10 items such as "I thought the system was easy to use". Items were rated on a five-point Likert scale, ranging from "strongly agree" to "strongly disagree". The total score ranges from 0 to 100, with higher scores indicating higher usability. The questionnaire has been demonstrated to be a reliable and superior assessment tool over comparative website usability questionnaires; however, its psychometric properties require further analysis (Wallergard et al., 2007).

Accelerometers:

The amount and intensity of the movement of the upper extremities were objectively measured by 2 Actical (Actical™ , MM; Mini-Mitter Co.) accelerometers. These small (28X27X10 mm) and light (17g) accelerometers can detect acceleration in all 3 planes (frequency range of 0.3-3 Hz, sensitive to 0.05-2.0 G-force, samples at 32 Hz). The reliability and validity of accelerometers for the UE of individuals with stroke has been established (Rand & Eng, 2011; Uswatte et al., 2000; Uswatte et al., 2005; Uswatte et al., 2006) but has not previously been used with individuals with stroke while playing video games.

The accelerometers were attached to a watch wrist band and worn around the weaker and stronger wrists. The total activity kilocounts for the weaker and stronger hands for playing 7 minutes (10 minutes minus 3 minutes of practice for each game) quantified the amount of UE activity for Bowling, Tennis and Ski.

Clinical assessments:

The following assessments were utilized to characterize the study population in terms of motor and cognitive ability: The upper extremity subtest of the Fugl-Meyer Motor Assessment (FMA; Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglind, 1975) was used to assess UE impairment of the hemiplegic arm while The Action Research Arm Test (ARAT; Lyle, 1981) assessed the functional ability of the UE. The Thumb Localization Test was utilized to assess participant proprioception in their weaker UE (Prescott, Garraway, & Akhtar, 1982) detecting the presence and severity of a proprioception deficit (mild, moderate, and severe). The Berg Balance Scale (BBS; Berg, Wood-Dauphinee, & Williams, 1995) was used to assess the ability to maintain balance while performing 14 functional tasks. Two cognitive screening tests were administered as well; the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) for general cognitive ability and the Star Cancellation Test (Wilson, Cockburn, & Halligan, 1987) for unilateral spatial neglect.

Procedure

Data collection included two sessions (a maximum of 1 week apart). The participants experienced the Wii games and filled in the feedback questionnaires within one session, while the clinical assessments were administered during the second session.

Prior to the Wii experience, the participants were provided with the two accelerometers and a personal avatar (termed a "Mii") resembling the participant was created by one of the researchers. The order of games experienced was counterbalanced to eliminate possible fatigue starting with either Bowling or Tennis, with Ski consistently used as the second game. For Ski, participants able to stand were asked to stand on the Wii Fit Balance Board; if they were unable to stand without assistance, they remained sitting in their wheelchair/chair with their lower extremities placed on the peripheral device.

Prior to playing the games, a researcher operated the Wii (selecting the game and the number of players) while using the Wiimote and explaining the procedure to the participants. After experiencing two games, the participants were requested to independently select and enter the last game. The assistance required by the participants (i.e., the number of verbal cues and/or physical assistance) to complete this task was recorded.

The specific instructions for each game were explained. Participants were provided with 3 minutes of practice with feedback from the researchers. Following this, each game was played for an additional 7 minutes. Once the 7 minutes elapsed, participants completed the SFQ-M and the Borg Exertion Scale. The SUS was administered once they completed the three games. Data from the accelerometers were then downloaded to a computer via the Actical Reader and analyzed using the Actical software.

Data Analysis

Descriptive statistics were used to characterize the study population, feedback questionnaires, clinical assessments, and accelerometer readings. Due to the small sample size, non-parametric tests were used. A Mann-Whitney U test (p value $< .05$) was performed to assess differences between inpatients and outpatients and between games with the weaker versus the stronger hand. When group differences were non-significant, data from outpatients and inpatients were pooled. A Wilcoxon signed-ranks test was used to determine differences in a participant's exertion, game experience and activity kilocounts between the three games.

Results

Fourteen participants were recruited; eight of the participants were outpatients (mean±SD = 36.5±15.2 weeks poststroke) and six were inpatients (5.8±5.0 weeks poststroke). Mean age was 56.0±14.8 years and ranged from 37 to 91 years. Table 1 shows additional demographic and stroke information regarding the participants. The groups did not differ significantly in terms of age (z= -1.5, p= .1) and years of education (z= -1.1, p= .3).

Table 1
Demographic and Stroke Information of Participants (N=14).

	Inpatients n=6 Mean ± SD	Outpatients n=8 Mean ± SD
Age (years)	63.3 ± 16.8	50.5 ± 11.1
Years of education (years)	13.5 ± 16.8	14.6 ± 1.8
	Number of participants	Number of participants
Gender (Male/Female)	4/2	6/2
Vocation (Customer service/ General labor/Desk job/ Health care)	2/2/1/1	2/2/4/0
Handedness (Right/Left/ Ambidextrous)	5/0/1	8/0/0
First/Recurrent stroke	4/2	7/1
Stroke Side (Right/Left/ Cerebellar)	5/1/0	5/2/1
Mobility (Independent ambulation/Ambulatory with aid/Non-ambulatory)	1/2/3	7/1/0
Visual status (Normal or corrected to normal/ Diplopia/Hemianopsia)	5/0/1	7/1/0

Table 2 presents the inpatient and outpatient participants' motor and cognitive abilities. Outpatients scored significantly better on the MMSE (Z= -2.3, p= 0.02), FMA (Z= -2.4, p= 0.02), BBS (Z= -2.8, p= 0.006) and Thumb Localization Test (Z= -2.7, p= 0.01), indicating that they were significantly higher functioning in terms of cognition, active movement of the UE and balance. They also had less proprioception impairment of the UE. No significant differences were found in the ARAT (Z= -1.7, p= 0.09) or in the Star Cancellation Test (Z= -0.4, p= 0.7), with only one participant presenting with signs of neglect (less than 44 stars on the Star Cancellation Test).

Table 2
Motor and Cognitive Abilities of the Participants.

	Inpatients n=6		Outpatients n=8	
	Mean ± SD	Range	Mean ± SD	Range
MMSE (0 - 30 points)	25.7 ± 2.5	23 - 29	28.8 ± 1.6	26 - 30
Fugl-Meyer Motor Assessment (0 - 60 points)	35.0 ± 21.4	7 - 54	55.9 ± 7.9	40 - 60
Thumb Localization (0 - 3 points, lower score indicates less proprioception impairment)	1.8 ± 1.3	0 - 3	0.13 ± 0.4	0 - 1
Action Research Arm Test (0 - 57 points)	28.8 ± 24.3	0 - 57	48.5 ± 12.9	25 - 57
Berg Balance Scale (0 - 56 points)	27.0 ± 21.8	3 - 49	53.5 ± 5.9	39 - 56

Approximately 60% of the participants in each group reported they had an interest in playing the Wii. Fifty percent of the inpatients and 87% of the outpatients reported they had watched other people play the Wii, while only 33% of the inpatients and 62.5% of the outpatients had actually played the Wii prior to the study. This prior experience did not correlate significantly with their experience or performance during the study.

Feasibility

Two participants (33.3%) from the inpatient group were able to hold the Wiimote with their weaker (=affected) hand to play Bowling and Tennis. In the outpatient group, six of the eight participants (75%) could hold and operate the Wiimote to play Bowling but seven participants (87.5%) were able to hold and operate the Wiimote to play Tennis. The UE of the participants that were able to hold the Wiimote and play Bowling and Tennis (n=8) had significantly more active movement (56.6±5.0 out of maximum 60 points compared to 34.0±21.3 on the FMA) (z= -2.4, p= .02), higher functional ability (53.1±8.4 out of maximum 57 points compared to 22.6±18.8 points on the ARAT) (z= -2.9, p= .003) and better proprioception (z= -2.6, p= .01) compared to the UE of the participants (n=6) who could not hold the Wiimote with their weaker hand. No significant difference in the level of enjoyment for Bowling and Tennis was perceived by the participants who could and could not hold the Wiimote in the weaker hand. However, a significantly higher total SFQ-M score for Bowling was obtained by the participants who held the Wiimote with their stronger hand (i.e. could not hold the Wiimote with their weaker hand) compared to the participants who could hold the Wiimote with their weaker hand (43.3±7.7 points compared to 33.1±8.4 points; z= -2.3, p= .02).

For Ski, all eight of the participants from the outpatients could stand on the balance board; however, only one participant from the inpatient group could stand while playing. When the participants who could stand while skiing (n=9) were compared to the participants who could not stand, a significant difference for the BBS was found (53.0±5.7 points versus 22.2±21.1 points; z= -2.7, p= .004). No differences in enjoyment or the total SFQ-M score was found between the participants who stood or sat while playing.

Usability

Usability scores were generally high, with non-significant differences (z= -1.2, p= 0.2) between the inpatient scores (65.8±28.5/100 points) and outpatient scores (84.1±16.1/100 points). There were also no significant correlations between total SUS scores and the motor and functional ability of the participants (clinical assessment scores), indicating that lower functioning individuals did not rate the Wii as significantly more difficult to use. Upon observation, the majority of participants could operate the Wii either independently (six participants) or with verbal cueing (seven participants) when selecting the third game. Only one participant required physical guidance to point and select the game using the Wiimote.

The Wii experience

All participants gave high scores on the SFQ-M for all three games played, with non-significant differences between inpatients and outpatients (Tennis z= -2.5, p= .8; Ski z= -0.5, p= .6, Bowling z= -0.3, p= .7). Borg scores for the three games were relatively low and without significant differences between both groups for the three games (Tennis Z= -1.1, p= 0.3; Ski Slalom Z= -1.6, p= 0.1; Bowling Z= -1.2, p= 0.2). This indicated that both groups had a generally positive experience with the Wii and perceived low levels of exertion. Therefore we combined both participant groups and compared the three games in terms of enjoyment, total SFQ-M and Borg scores (see Table 3). No significant differences were found for enjoyment and for the total SFQ-M scores between the three games; however, Ski was rated as significantly more exerting than Bowling (χ^2= 6.8, p= .03, z= -2.5, p= 0.01).

Table 3
Scores for SFQ-M and Borg Exertion Scale.

	Tennis Mean ± SD Range	Bowling Mean ± SD Range	Ski Slalom Mean ± SD Range
Enjoyment[a]	4.4±0.9	4.0±1.0	4.2±0.7
(0-5)	2-5	2-5	3-5
Total SFQ-M[b]	38.4±8.0	37.5±9.4	37.3±6.8
(0-50)	17-49	20-49	24-45
Total Borg[c]	11.6±3.6	10.4±2.2	12.5±2.0
(6-20)	6-17	6-13	9-15

[a]Enjoyment= The first item in the SFQ-M
[b]SFQ-M= The Short-Feedback Questionnaire-Modified
[c]Borg Test= Test of Perceived Exertion

There was a wide range in the performance of participants for the games played (see Table 4). Outpatients scored significantly higher in Tennis (Z= -2.7, p= 0.007) and Ski (Z= -2.5, p= 0.01), but not for Bowling (Z= -0.4, p= 0.7). Within 7 minutes, outpatients also managed to bowl significantly more frames (Z= -2.5, p= 0.01) than participants in the inpatient group. Performance across games was not compared due to differences in scoring for each game.

Table 4
Participant Game Performance and Total Games Played Within 7 Minutes.

	Inpatients		Outpatients	
	Mean game score	Mean number of games played	Mean game score	Mean number of games played
	Mean range	Mean range	Mean range	Mean range
Tennis	5.7±6.7	3.0±1.3	25.4±15.7	4.0±0.9
	0-18.3	1-5	7.5-50.0	3-5
Ski Slalom[a]	114.7±20.9	6.7±0.52	81.8±19.7	7.3±1.3
	97.5-144.5	6-7	45.8-106.1	6-10
Bowling	109.6±45.8	0.7±0.4	82.9±49.1	1.3±0.4
	77.3-142.0	0.2-1	45.0-142.2	0.9-2

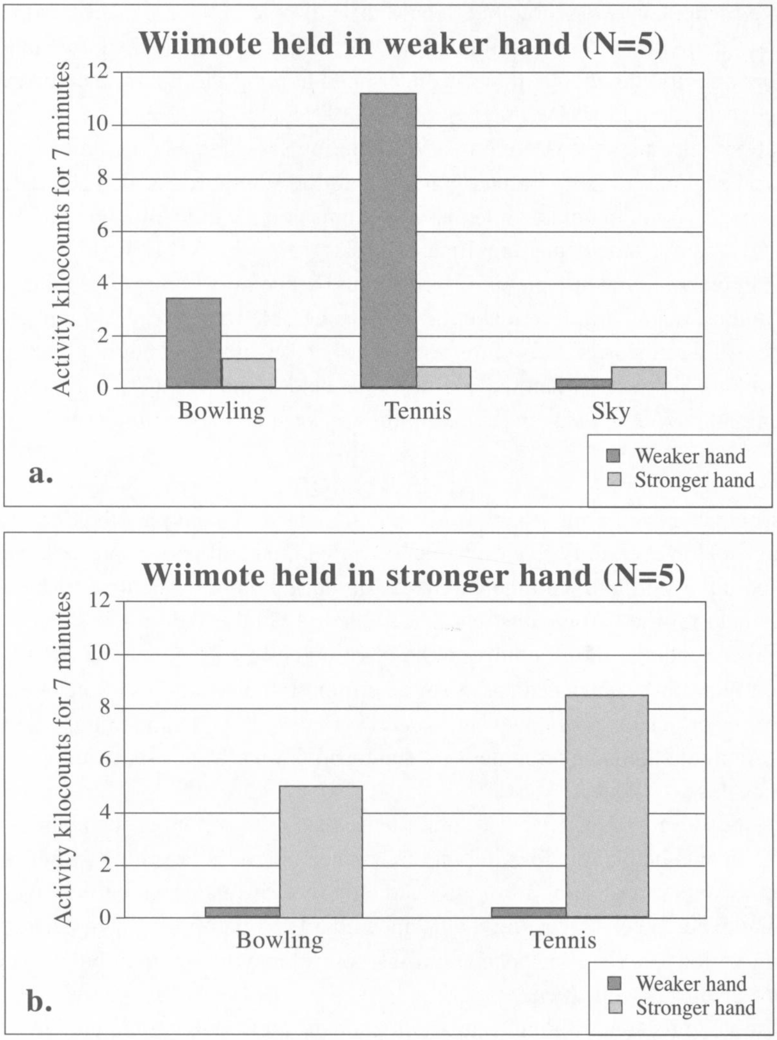
Note. The score and number of games was recorded and used to calculate means. Incomplete games were calculated as percentages of games played. For instance, 4/10 frames of bowling equals 0.4 of a total game played.
[a] For Ski-Slalom - lower score = better performance.

Upper extremity activity
The accelerometer readings while playing the three games was available only for 10/14 participants due to logistical difficulties. The activity kilocounts and intensity of the movement of the weaker and stronger wrists for Bowling, Tennis and Ski are presented in Table 5 and Figure 1 (a, b).

Table 5
The Mean ± SD Accelerometer Activity Kilocounts and Intensity of Movement From the Weaker and Stronger Hands While Playing Bowling, Ski and Tennis.

			Bowling	Tennis	Ski
Wiimote held in weaker hand (n=5)	Weaker	Activity kilocounts	3.4 ± 1.1 2.1-4.5	11.2 ±2.0 9.5-14.5	-
		Intensity	2.0± 0.0 2-2	2.7±0.4 2-3	-
	Stronger	Activity kilocounts	1.2 ± 1.0 0.1-2.4	0.6±0.4 0.02-1.1	
		Intensity	1.6 ±0.54 1-2	2.0 ±0.7 1-3	-
Wiimote held in stronger hand (n=5)	Weaker	Activity kilocounts	0.3 ±0.2 0.01-0.7	0.3 ± 0.3 0.03-0.8	-
		Intensity	1.4 ± 0.5 1-2	1.5 ±0.5 1-2	-
	Stronger	Activity kilocounts	5.0 ±3.5 0.9-10.2	8.6±2.8 6.0-12.2	-
		Intensity	2.0 ± 0 2-2	2.7 ±0.5 2-3	-
Not holding the Wiimote (n=10)	Weaker	Activity Kilocounts	- -	- -	0.2 ± 0.3 0.008-1.0
		Intensity	-	-	1 ± 0 1-1
	Stronger	Activity kilocounts	-	-	0.7 ± 0.5 0.04-1.4
		Intensity	-	-	1 ± 0 1-1

Figure 1
Accelerometer activity kilocounts during 7 minutes of playing each of the games: Bowling, Tennis and Ski: (a) while the participants (N=5) held the Wiimote in their weaker hand. Note that for Ski, the Wiimote was not held at all; (b) while the participants (n=5) held the Wiimote in their stronger hand.



Five participants were able to hold the Wiimote in their weaker hand; this elicited more movement in this hand compared to the stronger hand that was not holding the Wiimote (although not statistically significantly). Additionally, more activity kilocounts were elicited in the weaker hand holding the Wiimote while playing Tennis compared to playing Bowling and Ski ($\chi^2 = 10$, $p < .007$). Five participants were not able to hold the Wiimote in their weaker hand and therefore held the Wiimote in their stronger hand. This elicited significantly more activity kilocounts in the stronger hand holding the Wiimote compared to the weaker hand for Bowling ($z = -2.0$, $p = .04$) and Ski ($z = -2.0$, $p = .04$). Note that participants weren't holding a Wiimote for Ski-Slalom. When the participants used their stronger hand to hold the Wiimote this also elicited more activity kilocounts while playing Tennis compared to Bowling and Ski but it was not statistically significant.

Interestingly, while playing Bowling and especially Tennis, when the Wiimote was held in the weaker hand, considerable movement (although less intense) was measured also in the stronger hand, which was not holding the Wiimote. However, when the Wiimote was held in the stronger hand, only minimal movement was measured in the weaker hand not holding the Wiimote.

Discussion

Participants from both groups were able to understand and play the different games. However, only five outpatient and two inpatient participants were able to hold the Wiimote with their weaker arm during games. The lowest score obtained for the participants who were able to hold the Wiimote in their weaker hand was 47/60 points on the FMA and 33/57 points on the ARAT. In the future, these scores can assist in determining the suitability of the Wii as a tool for our clients. Mouawad et al. (2011) reported that bandaging the hand on the Wiimote helped overcome weak handgrip but it was not specified in which cases this was done.

The Wii Fit game was also found to be feasible, with more than half of the participants being able to stand on the balance board. Interestingly, whether participants stood or sat during the game did not correlate to their positive game experience, suggesting the balance board can be utilized with participants with various levels of balance and trunk control and with non-ambulatory participants as well. A cut off score of 40/57 points for the BBS seems to be reasonable for determining if a participant can safely stand while playing.

System usability incorporates user effectiveness and efficiency in meeting objectives and user's satisfaction with achieving those objectives (Finstad, 2006). The usability of the with Wii with this population was assessed after providing the participants with the opportunity to select and enter the third game independently. Both groups rated the usability of the Wii as high. Specifically, participants reported the Wii system as being easy to use, well integrated, and easy to learn. Independent use of a gaming system is important to ensure on-going use of this system, especially for home use. Our results are consistent with research examining EyeToy use in a stroke population (Rand et al., 2008) and with the findings from Mouawad et al. (2011), in which seven individuals poststroke practiced playing Wii Sport games at home for 2 weeks. Most of their participants were highly satisfied, with a mean score of 9.4 ± 0.4 on the visual analogue scale, however the control of the Wiimote buttons was reported to be difficult and frustrating and the timing and feedback from the Wii Games also caused frustration (Mouawad et al., 2011).

Overall, participants reported their experience with the Wii to be positive. These findings are comparable to the experience of individuals with stroke who played games on the Sony PlayStation 2 EyeToy (Rand et al., 2008). In addition, these results are consistent with research using the Wii in other populations, in which high user preference was provided based on overall positive experiences with the system (Bell et al., 2009; Labbe et al., 2009; Mouawad et al., 2011). These findings have practical implications as high enjoyment is predictive of engagement in activities (Tauer & Harackiewicz, 2004). Specifically, participants are more likely to engage in therapy and be motivated to perform repetitive movements if the task meaningful and enjoyable (Jang et al., 2005).

Though there was no over-arching relationship between functional ability and game experience, participants with decreased UE function reported a more positive experience during Bowling. This is congruent with our feasibility results, as it is likely that participants with decreased UE function used their non-weak arm to play Bowling. This finding may result from the fact that Bowling requires the greatest fine-motor demands, and this area of function was not compromised in participants playing with their non-weak UE.

Overall, exertion scores were low, with a non-significant relationship to functional ability. This could be explained by the fact that all participants were sitting during Wii Sports and that their experience was limited to a total of 10 minutes per game. Further, these results are consistent with studies examining other commercially available game consoles among individuals with stroke

(Rand et al., 2008). Higher Borg ratings were found for Ski in comparison to Bowling, since nine of the participants stood. Individuals with decreased balance also reported higher levels of exertion.

The Wii was found to be sensitive to the functional levels of participants with stroke in terms of performance; the higher functioning participants in the outpatient group obtained higher scores for the games.

Accelerometer readings provided an objective measure of the amount of active movement elicited by both arms while playing. Since the repetition of active movement is important for rehabilitation, the quantification of movement while using the Wii is essential. The accelerometers detected different movement patterns for the participants who were able to hold the Wiimote in their weaker hand compared to the participants who were unable to do so. Significantly more activity kilocounts were elicited in the stronger hand of the person holding the Wiimote compared to his/her weak hand, which could not hold the Wiimote. In other participants, more activity kilocounts were elicited in the weaker hand compared to the stronger hand when his/her weak hand was holding the Wiimote; however this difference was not significant. Since the weaker hand in this case had more active movement than the former, it is possible that the differences are smaller. More so, playing the games with the weaker hand was obviously still an effort which incorporated more movement from the stronger hand as well.

Overall, different levels of movement were elicited for the hand holding the Wiimote. Increased levels of movement were found for individuals who held the Wiimote in their weaker hand compared to individuals who held the Wiimote in the stronger hand. This perhaps implies that gross and non-isolated movements were performed by the weaker hand. Upon observation, players seemed to use their entire upper body rather than isolated movements of the involved UE. If the therapeutic goal is to enhance active movement of the weaker UE, therapists might need to assure that correct movement patterns are performed. Similar observations of non isolated movements were reported in individuals with stroke (Rand et al., 2008) who played games on the Sony PlayStation 2 EyeToy, which is a video capture system.

The accelerometer readings were also found to be sensitive to the game played; Tennis elicited more active movements and more intense movement than Bowling and Bowling elicited more activity kilocounts compared to Ski. Since Ski is operated by weight shifting on the balance board, the UE movements are due to balance reactions and not purposeful UE movements. Greater energy expenditure for playing Tennis compared to Bowling has been reported for adolescents (Graves, Stratton, Ridgers, & Cable, 2008), but this is the first study to measure movement elicited in individuals with stroke while playing the Wii. Further research with larger samples wearing accelerometers is recommended.

Overall, if the Wiimote can be held with the weak hand, playing the games can encourage active purposeful movement of the weak UE. Wii Fit games, which encourage weight shift and postural control, may be used to improve sitting or standing balance of individuals at different stages. Using the Wii to increase activity tolerance may be a general therapeutic goal as well. Future studies should explore the effectiveness of using the Wii as an intervention tool, specifically, for improving the functional ability of the weak UE.

Limitations

The current study is based on pilot data. The low sample size, especially of the accelerometer data, may limit the generalizability of the findings. However a heterogeneous sample of low to higher functioning participants was included.

Conclusion

The feasibility and usability of the Wii with individuals with stroke at different recovery stages, indicates that this system is applicable for therapeutic use during stroke rehabilitation. The enjoyment experienced while playing the games may encourage extensive usage leading to repetition of purposeful active movement, which is crucial for motor recovery.

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APPENDIX A

Game	Accessories	Game setup	Movements
Bowling	Wiimote* used in fashion of bowling ball. The game requires pressing A/B buttons simultaneously on the Wiimote with index finger and thumb and release at top of swing.	Bowl game of 10 frames.	In addition to grasping the Wiimote + finger movements to operate the Wiimote. Gross motor: extension, flexion of shoulder and elbow as player swings arm. Radial and ulnar deviation of wrist.
Tennis	Wiimote* used in fashion of tennis racquet. No button pressing on the Wiimote required.	Double game of tennis against computer.	In addition to grasping the Wiimote. Gross motor: extension, flexion of shoulder and elbow as player swings arm. Abduction of shoulder with swing. Radial and ulnar deviation. Flexion/extension of wrist as player swings "racquet".

Ski-Slalom	Use of Balance Board coupled with WiiFit. Multi pressure sensor that measures centre of balance and weight. Board interprets movements of both feet as player weight shifts. Feedback provided via audio inputs.	Stand with feet placed on Wii Fit Balance Board. If participant cannot stand - sit with feet placed on board. Ski between flags in downhill fashion.	Shift weight to left and right lower extremity to steer direction. Shifting weight forward and back to change acceleration.

* Wiimote - Resembles intuitive use of remote controller. Motion sensing capacity that detects gestures and pointing coupled with ability to sense acceleration. Feedback provided via basic rumble and audio inputs.