

**An exploratory study examining the potential benefit and appropriateness
of the Nintendo Wii as a physical activity tool in adults aged ≥ 55 years**

Abstract

This study investigates the physical exertion of playing the Nintendo Wii® (Wii) and determines the appropriateness and potential benefit of it as a physical activity tool for older adults. Twenty healthy adults (aged 61 ± 6 yrs) took part in a single session using a selection of the Wii Sports and Wii Fit games. During the gameplay session heart rate and perceived exertion were measured. Pre- and post-session we investigated mood using the Positive and Negative Affect Schedule (PANAS) and cognitive function (i.e. aptitude, abstract reasoning, and problem solving) using the test of non-verbal intelligence (TONI-IQ) and trail B tests. We also gathered subjective feedback from participants using semi-structured interviews and questionnaires. Three of the game activities (hula-hoop, rowing squat and leg extension) were identified to reach a moderate level of heart rate intensity, with one activity (jogging) corresponding to a vigorous level. We identified that post-session PANAS positive subscale scores were greater than pre-session scores ($p < 0.01$). There was a reduction in the time to complete the TONI-IQ test from pre to post-session ($p < 0.05$). Findings from this data identify that: some Wii activities were of an intensity required for health benefits; a single Wii activity session can result in positive mood changes and the Wii interface is generally acceptable and appropriate for this older age adult group. Further randomised controlled and longer term intervention trials are needed to determine the effectiveness of Exergame activity programmes.

Keywords

Nintendo Wii, physical activity, older adults, mood, cognitive function, exertion.

Abbreviations

BMI: Body Mass Index; SPAQ: Scottish Physical Activity Questionnaire; HR: Heart Rate; RPE: Rate of Perceived Exertion; ACSM: American College of Sports Medicine; HRmax: maximum Heart Rate; PANAS: Positive and Negative Affect Scale; PANASpos: positive scale on the PANAS; PANASneg: negative scale on the PANAS; TONI IQ: Test Of Nonverbal Intelligence.

1.1 Introduction

1.1.1 Background

Current physical activity guidelines for adults are to accumulate at least 150 minutes of moderate intensity activity per week (Department of Health, 2011). Moderate intensity is generally described as being activity which causes a noticeable increase in heart and breathing rate. Sedentary lifestyles have resulted in an estimated 60% of the world's population failing to comply with physical activity guidelines (WHO 2004). According to the World Health Organisation, physical inactivity is the fourth leading risk factor for global mortality (2011). The National Centre for Chronic Disease Prevention and Health Promotion in the United States estimates that by the age of 75, "a third of men and half of all women do not engage in any regular physical activity" (1999). In the UK alone, excluding the cost of obesity, sedentary lifestyles are estimated to cost the taxpayer £8.2 billion in healthcare (Allender et al. 2007). As such, appropriate intervention is paramount in reducing healthcare costs and the long term risk of disease in later life. In particular, increased participation and adherence to physical activity is part of national strategies for boosting mental capital towards long-term fitness and mobility, recognising that the effects of chronic disease can take many decades to manifest (Chao et al. 2000).

Mid-to-older aged adults potentially have the most to gain from becoming regularly active as physical and cognitive functioning often deteriorates with age (Anstey and Low 2004). Regular physical activity is known to result in physiological, psychological and quality of life benefits (O'Donovan et al. 2010) and has been shown to slow the decline in cognition found with increasing age even in previously sedentary adults (Nelson et al. 2007). Balance training is particularly important in older adults as it can reduce falling risk (Ekwall et al. 2009) - a risk which rises with increasing age (Lehtola et al. 2006). Similarly, strength training can decrease the risk of osteoporosis (Sharkey et al. 2000) and regular strength and flexibility training can benefit physical functioning and mobility (Nelson et al. 2007).

1.1.2 Exergaming

Exergaming is the term given to video games that facilitate physical exercise (Mhurchu et al. 2008), and are often marketed on the premise that they can improve both physical and mental wellbeing. Representing one of the largest growing segments in the games industry, computer-simulated experiences can replace the need to go to the gym or exercise class, which, at least potentially, is seen to be advantageous for those people who are either limited by time and cost, are housebound due to medical reasons or caring responsibilities, or simply prefer to exercise at home. Exergaming in this context offers consumers greater control over their personal health and fitness, and as Thin describes, “in general has the potential to transform exercise that is tedious and discomforting into a form that is appealing”. (2010, p.2). In particular, with a worldwide sale of approximately 70 million units (Nintendo 2011), the Nintendo Wii has become a familiar console in family-orientated gaming, facilitating a more physical experience than traditional forms of gameplay. With the possibility of attracting many ‘non-gamers’, fitness games for the Wii include: bowling, tennis and boxing on the Wii Sports; and aerobic, muscular strength, endurance yoga and balance activities for the Wii Fit. These games typically consist of a virtual avatar, or Mii character, that presents a two dimensional caricature of the user on-screen. User interaction can involve the use of a hand held remote (Wii mote) with a sensor bar for motion sensing, which can detect acceleration in three dimensions, and a wireless balance board for lower body movement and tracking body mass index. Wi-Fi connection to the Internet also enables the receiving of messages, software updates and the downloading of game content.

Attempting to address the issue of rising levels of obesity, the Department of Health in the UK have endorsed the use of the Wii Fit Plus as an exergaming tool (Wallop 2009). Nevertheless, despite the potential health benefits of exergaming, there remains a lack of scientific evidence to determine the efficacy of games like the Wii Sports and Wii Fit on the health of participants and in particular those in older age groups.

Wollersheim et al. (2010) conducted a pilot study with older women (mean age 74yrs) of a six week intervention, including 12 supervised sessions of the Wii. Energy expenditure (EE) was measured before (in three separate occasions over 6 weeks for 20 minutes) and during the intervention period

(during Wii play sessions) using accelerometers (RT3) and psychosocial benefits explored through end of study focus groups. Compared to EE measurements before the Wii intervention, during Wii play, maximum energy expenditure was higher but this was offset by the fact that they also had longer resting periods between activities and therefore there was no difference in total energy expenditure. Qualitative feedback identified participants' experienced positive benefits from participation. Women felt the Wii opened a new opportunity to engage with physical activity again and that it stimulated both their mind and body and took them out of their "comfort zone". They identified strong social benefit and a greater relatedness to younger members of their family. Agmon et al (2011) also explored the safety and feasibility of using the Nintendo Wii to improve balance in older adults (mean age 84yrs) with impaired balance. Participants were asked to play the Wii for at least 30 minutes, three times a week for three months and received weekly supporting phone calls. Participants completed the BBS, 4-Meter Timed Walk test, and the Physical Activity Enjoyment Scale at baseline and 3 months. Semi structured interviews were conducted at the 3-month and they also completed a paper log of their exergame play. Results reported that participants safely and independently played a mean of 50 sessions, each session having a median duration of 31 minutes. Participants rated high enjoyment of game play and expressed experiencing improved balance with daily activities and, similar to the Wollersheim study, a desire to play exergames with their grandchildren. Berg Balance Scores increased from 49 (2.1) to 53 (1.8) points ($P = .017$). Walking speed increased from 1.04 (0.2) to 1.33 (0.84) m/s ($P = .018$).

Rosenberg et al. (2010) conducted a pilot study with 19 older adults (age range 63 -94yrs) with subsyndromal depression playing the Wii Sports three times a week for a three month period. Significant improvements were reported in depressive symptoms, mental health-related quality of life (QoL), and cognitive performance but not physical health-related QoL. In addition no major adverse events were reported. The authors concluded that such games may be a novel way of reducing depression in older cohorts but that further randomised controlled trials were required. Graves et al (2010) found that energy expenditure and heart rate with younger and older adults whilst playing the Wii was greater than during handheld gaming but lower than treadmill exercise; however the heart rate during Wii play fell below the intensity required for maintaining cardiorespiratory fitness. Group

enjoyment rating was greater for Wii balance and aerobics compared with treadmill walking and jogging.

Assessment of the usability and appropriateness of the Wii for older adults is critical to determine current use and to inform future development for tailoring the interface to different groups of the population. Assessment of usability will also help to inform methods for sustaining continued use of such an exercise programme. A small number of studies noted above have assessed actual exertion level in different groups of the population whilst playing the Wii. This is important to determine whether activity while playing the Wii is at a sufficient intensity to provide health benefit. In normal play conditions however players will self-determine their perceived exertion level. It is important therefore to explore if there is a difference between actual exertion level and perceived exertion level. If large differences are found this may warrant the addition of an objective method of monitoring exertion level to the interface.

1.1.3 Current study outline and objectives

This paper reports the findings of an exploratory study examining the appropriateness and potential benefit of the Nintendo Wii as a physical activity promotion tool for older adults. This study had three main objectives: 1) to measure the actual and perceived exertion rate of playing the Wii in a sample of healthy older adults during a single gaming session; 2) to examine the immediate effects of the session on mood and cognitive function; and, 3) to determine the appropriateness of the Nintendo Wii as a physical activity tool for older adults.

1.2 Methods

1.2.1 Participants

Twenty participants (6 men and 14 women, mean age 61 ±6 years (±SD)) were recruited through University exercise classes, email and word of mouth. The inclusion criteria included: 1) aged ≥55 years; 2) having no previous experience of using the Nintendo Wii; 3) having no medical contraindications to exercise participation; and, 4) having no known cognitive impairments (e.g., dementia). The exclusion criteria followed physical activity participation guidelines by Greig et al. (1994), including the taking of beta-blockers or digoxin medication which are known to effect heart rate. Ethical approval was obtained from the University of Strathclyde. All participants provided written informed consent prior to their participation. Testing was conducted either at the laboratory (n=17) or in the participant's home for those that did not live near the university (n=3). In each case the same protocol was completed. Each session lasted approximately 120 minutes.

1.2.2 Pre-session measurements

Physical activity, blood pressure and body mass index were measured to provide descriptive information of the sample group and to assess suitability for exercise. The Scottish Physical Activity Questionnaire (SPAQ) was administered by either post or email to participants prior to their involvement in the study. This questionnaire requires participants to recall their physical activity participation of a moderate to vigorous intensity (a description of each intensity is provided on the questionnaire) over the past week and has been shown to be a valid and reliable measure in adults (Lowther et al. 1999). Total leisure and occupational related physical activity were recorded in minutes per week. Blood pressure was measured three times in a seated position, after at least a 5 minute period of rest, and with at least one minute rest between measurements. Height and weight were measured and BMI calculated (kg/m^2).

A battery of tests was then administered to determine if playing the Wii games could have a significant impact on mood and cognitive function. Mood was first assessed using the Positive and Negative Affect Schedule (PANAS) which is a valid and reliable tool to measure personality states (Watson et al. 1988). The questionnaire consists of 24 items for which participants rate how they have felt over the past month on a five-point Likert scale (1 = being not at all true; 5 = being very true), and

are totalled to independently give a positive (PANASpos) and negative (PANASneg) subscale score. The greater the PANASpos total and lower the PANASneg total the more favourable the overall mood of the individual. Thus an increase in PANASpos and decrease in PANASneg represents an overall improvement in mood, whilst a decrease in PANASpos and increase in PANASneg indicates a decline. In addition, cognitive function was also assessed using the test of non-verbal intelligence (TONI-IQ, third edition) and trail task B. These valid tools are easy to administer and were appropriate to the study sample. The TONI-IQ measures intelligence, aptitude, abstract reasoning and problem solving and consists of 45 cards with pictures and a problem to solve (Brown et al. 1997). Five training cards were used to explain the aim of the task and participants were asked if they understood before commencing the test. A facilitator noted the participants' answer for each of the cards. When 3 out of 5 consecutive cards were answered incorrectly the test was stopped, otherwise the participants carried on until all 45 cards were completed. Scores were calculated by totalling the number of correct answers. Time to completion in minutes and seconds were recorded. Participants were told to focus on giving a correct answer rather than the speed of answering. Finally participants were asked to complete the trail B test. This test assesses visuomotor tracking and attention (Hester et al. 2005) and consists of a series of ascending numbers and letters in dots spread randomly on paper. Participants were asked to join the dots in pen/pencil in an alternating and ascending order (e.g. beginning on the number 1; 1-A, 2-B and finishing on the number 13) as quickly as possible. Time to completion was recorded in seconds.

1.2.3 During session measurements

During each session objective exertion levels (heart rate) were recorded continuously by downloadable heart rate monitors¹. Predicted heart rate maximum for each individual was determined using the equation $208 - (0.7 \times \text{age})$ (Tanaka et al. 2001) with the predicted heart rate being rounded down to the nearest whole number. In order to categorise heart rate intensity, average and maximum heart rate during the sessions were recorded in beats per minute and expressed as a percentage of predicted heart rate maximum (%HRmax). Immediately after each individual activity heart rate was

¹ Polar Electro heart monitor - <http://www.polarusa.com/us-en/>

noted by the facilitator and the %HRmax calculated. Heart rate during the Wii physical activity session was categorised by intensity using American College of Sports Medicine guidelines (ACSM 2006) identified in Appendix A.

After each activity, participants were also asked to rate their level of exertion by pointing to the appropriate number on a Rate of Perceived Exertion (RPE) scale poster. Borg's (1998) RPE scale measures subjective feelings of physical exertion during exercise. The scale ranges from 6 which correspond to sitting or lying down; up to 20 which relates to extremely hard exercise which for safety reasons would require terminating the activity. Below 12 on this scale corresponds to a light intensity, 12 to 14 a moderate intensity and 15 and above a vigorous intensity (this is also in Appendix A, allowing comparison with heart rate intensity categories).

1.2.4 Post-session measurements

Post session measurements were completed immediately after the Wii activity session. Participants completed the PANAS based on how they felt immediately after the Wii session to assess mood. Cognitive function was assessed using parallel tests; the TONI-IQ with a different set of 45 cards and the trail B test with the numbers and letters spread differently from the pre-session test. Qualitative feedback on the Wii session was obtained through semi-structured interviews and through a short feedback questionnaire (Appendix B and C). Interviews and questionnaires asked participants to express their views of the suitability, feasibility and acceptability of using the Nintendo Wii (including the individual components) for this group of the population. Discussions were audio-recorded, transcribed verbatim and thematically analysed. Once the study was complete, participants were debriefed via a results summary which was emailed/mailed out.

1.2.5 Exergaming tasks

For the actual gaming tasks, each session consisted of 9 activities using the Wii sports and Wii Fit games. The order of the activities was: step aerobics, bowling, hula-hoop, jogging, torso and waist twists, rowing squat, leg extension, yoga breathing and half-moon yoga pose. Individual activity duration is noted in the first column of Table 2. Based on ACSM recommendations each session was constructed like a senior workout programme, consisting of a set of warm up, aerobic, muscle and

then relaxation/yoga exercises. The gaming order and task selection was specifically designed to decrease the risk of injury and to optimise the body for exercise participation.

As part of the briefing phase, the facilitator demonstrated to participants how to use the Wii remote and which buttons to press to navigate the games. For seven of the nine activities the game continued for a set time. The exceptions were the hula-hoop and bowling games. If the user did not move in the correct motion during the hula-hoop task then the hoop dropped to the ground and the game stopped early. In this instance the participant was given another opportunity to play the same game. During the bowling game, participants took varying times to play a shot.

1.2.6 Data analysis

The group mean heart rate and heart rate expressed as a percentage of maximum heart rate (%HRmax) was calculated for the full Wii activity session. In addition the group mean heart rate and range and mean %HRmax and range, in addition to mean RPE and range for each individual activity was calculated. Changes in PANASpos and PANASneg scores, TONI-IQ score, TONI-IQ time to completion and trail B test time to completion pre- and post-sessions were analysed. Normality for these variables was assessed using the Kolmogorov-Smirnov test. For normally distributed data ($p > 0.05$) paired-sample *t* tests were used to find changes between pre and post-session measures. When the data was not normally distributed ($p < 0.05$) a Wilcoxon signed-rank test was used to determine differences between pre- and post-session values. Significance was set at $p < 0.05$ and data was analysed using SPSS.

1.3 Results

1.3.1 Descriptive data

Descriptive data for the participants can be found in Table 1. All participants successfully completed all the game activities. Using the SPAQ results, the mean total physical activity time was 847.30 ±909.28mins/week (range 110-4500mins/week), however we identified that this data was not normally distributed. After removing the data for one highly active participant, it was found to be normally distributed (mean = 655.05 ±304.10minutes/week). Outliers were included in all analysis given the small sample size used.

Table 1. Descriptive data for study participants, (n=20).

| Measure | Mean ±SD |
|--|----------------|
| Age (years) | 61.8 (±6.6) |
| BMI (kg/m ²) | 26.5 (±4.7) |
| Predicted maximum heart rate (bpm) | 164 (±4) |
| Resting systolic blood pressure (mmHg) | 147.9 (±17.3) |
| Resting diastolic blood pressure (mmHg) | 85.1 (±9.7) |
| Reported total physical activity (mins/week) | 847.3 (±909.3) |
| Reported leisure physical activity (mins/week) | 644.6 (±434.5) |
| Reported physical activity at work (mins/week) | 184.3 (±568.1) |

SD = standard deviation, BMI = Body Mass Index

In Table 1, the diastolic measurements relate to the blood pressure between contractions of the heart, while systolic, the blood pressure during contractions. Diastolic is classified as the minimum blood pressure and systolic the maximum.

1.3.2 Objective one: Physical exertion during Wii exergaming

Wii session duration ranged from 38-58 minutes (mean = 44 ±5.0mins). Average heart rate over the full Wii session was 94±10 beats per minute (bpm), (56±7%HRmax) this corresponds to a light

exercise intensity and maximum heart rate was 138 ± 16 bpm ($83 \pm 11\%$ HRmax). The average heart rate and RPE immediately after each Wii activity are shown in Table 2. Heart rate during three of the activities (hula-hoop, rowing squat and leg extension) corresponded to a moderate intensity, with a vigorous intensity during the jogging activity. All other activities were of a light level of exertion. In comparison rate of perceived exertion intensity categories for individual activities were similar with three activities (hula-hoop, jogging, and leg extension) corresponding to a moderate intensity and all other activities corresponding to a light intensity.

Table 2. Heart rate (during) and Rate of Perceived Exertion (immediately after) each of the Wii activities (n=20).

| Activity & duration | Mean heart rate \pmSD (bpm) | % HRmax \pmSD | Mean heart rate range (bpm) | % HRmax range | Heart rate intensity category | Mean RPE \pmSD | Mean RPE range | RPE intensity category |
|---------------------------------|---|-----------------------------------|------------------------------------|----------------------|--------------------------------------|------------------------------------|-----------------------|-------------------------------|
| Step aerobics (3 mins) | 94 \pm 2 | 57 \pm 7 | 72-121 | 42-71 | Light | 10 \pm 2 | 6-13 | Light |
| Bowling (4 mins) | 87 \pm 2 | 53 \pm 7 | 63-109 | 37-64 | Light | 10 \pm 2 | 6-15 | Light |
| Hula-hoop (3 mins) | 120 \pm 4 | 73 \pm 11 | 83-160 | 50-94 | Moderate | 12 \pm 2 | 10-16 | Moderate |
| Jogging (3 mins) | 131 \pm 4 | 80 \pm 12 | 100-173 | 59-102 | Vigorous | 14 \pm 2 | 10-17 | Moderate |
| Torso and waist twists (2 mins) | 101 \pm 2 | 62 \pm 8 | 74-120 | 44-78 | Light | 11 \pm 2 | 6-16 | Light |
| Rowing squat (1 min) | 107 \pm 2 | 65 \pm 8 | 86-135 | 51-79 | Moderate | 11 \pm 2 | 6-16 | Light |
| Leg extension (1 min) | 112 \pm 2 | 68 \pm 8 | 88-131 | 52-80 | Moderate | 12 \pm 3 | 6-17 | Moderate |

| | | | | | | | | |
|-------------------------|--------|--------|--------|-------|-------|------|------|-------|
| Yoga breathing (2 mins) | 91 ±3 | 55 ±10 | 63-128 | 37-77 | Light | 10±2 | 6-13 | Light |
| Yoga half moon (2 mins) | 101 ±3 | 62 ±9 | 74-133 | 45-80 | Light | 11±3 | 6-15 | Light |

SD = standard deviation, bpm = beats per minute, HRmax = maximum heart rate, RPE = rate of perceived exertion.

1.3.3 Objective two: Mood and cognitive effects

The mean PANAS, TONI-IQ and trail test measures pre and post-session are detailed in Table 3.

PANASneg scores and TONI-IQ time data were not normally distributed therefore mean scores are presented for illustration but median scores were used for analysis. On average the PANASpos score was significantly greater post- than pre-session, ($t(19) = -3.81, p = 0.001, r = 0.59$). PANASneg scores were significantly higher pre-Wii session (median = 20.00) than post-Wii session (median = 13.50), $z = -3.79, p = 0.000, r = -0.85$. For TONI-IQ scores, there was no significant difference between pre- and post-session score values ($t(19) = 6.98, p = 0.493, r = 0.16$). By contrast, TONI-IQ time was significantly longer pre- (median = 8.03) than post-session (median = 5.70), $z = -2.17, p = 0.030, r = -0.50$. We found no significant difference in the mean time to complete the trail B test pre- to post-session ($t(15) = -0.40, p = 0.698, r = 0.10$).

Table 3. Immediate changes in mean PANAS, TONI-IQ and trail test measures from pre to post Wii session

| Outcome measure | Pre-session mean ±SD | Post-session mean ±SD | Significance (pre-post) |
|--------------------------|----------------------|-----------------------|-------------------------|
| PANAS positive score | 47.3 (±7.3) | 51.7 (±6.2) | $p = 0.001^*$ |
| PANAS negative score | 21.3 (±7.1) | 14.7 (±3.5) | $p = 0.000^*$ |
| TONI-IQ score | 28.7 (±8.7) | 27.8 (±7.1) | $p = 0.493$ |
| TONI-IQ time (mins.secs) | 10.3 (±6.4) | 8.5 (±6.7) | $p = 0.030$ |
| Trail test time (secs) | 59.7 (±24.2) | 61.2 (±20.9) | $p = 0.698$ |

* Significance at 0.01 level. SD = standard deviation

1.3.4 Objective three: appropriateness of Nintendo Wii for older adults

The jogging, hula-hoop, bowling and yoga were reported as being the most enjoyable activities to play, mainly because of their perceived health benefits, fun or sense of achievement to complete. In this case, these are three of the games that gained highest intensity. The less favourable games were the step and torso, and waist twist exercises that were reported as being more difficult to coordinate. In terms of input controls, the Wii remote was rated as being very usable, with minor criticism when swinging or raising arms above the head. By contrast, the force plate received mixed response in its usage. On the one hand, it drew criticism because physical actions were not always detected by the system, such as in the hula-hoop game. On the other hand, individuals were cautious of falling off, particularly when bending over. Representation of the games were felt to be suitable for this age group, with recommendations for a fit instructor something to aspire too. Nobody reported the activities unsuitable for their age group.

Despite this, many of the participants thought the Wii would be useful for others in their age group, rather than themselves. Often it was the case that the perceived advantages were for those people who were housebound or in poor physical health, forming of physical intervention and social camaraderie. Beyond the novelty factor per se, questions were raised over the motivation and self-discipline to sustain usage ('I *could* stick to it, whether I *would* is a different matter'). Based on their present experience, thirteen participants reported that they would use the Wii again, five were unsure and two would not use it beyond the study.

1.4 Discussion

In more detail, we now discuss on our findings, their implications, as well as constructively describe the limitations of this work.

1.4.2 Objective one: Physical exertion during Wii exergaming

Heart rate during the Wii activities ranged from 87-131 bpm. This deviation in results can account to both the amount of effort that is required to play each game, and the amount of personal effort put into them. Participants were identified to work at a light intensity (53%HRmax) whilst playing the Wii Sports bowling. This is comparable to studies by Graves et al. (2008) and Graf et al. (2009) who found the intensity of playing Wii Sports bowling in children to be of a light intensity with heart rates of 49%HRmax and 48%HRmax prospectively. Similarly, Wollersheim et al. (2010) reported the Wii bowling to be of low energy intensity in older adults, although no specific details are provided. For the Wii Fit aerobics in older adults, Graves et al. (2010) found participants were working at 57%HRmax. This is similar to our mean step aerobics scores ($57\pm 7\%$ HRmax)) but lower to the other aerobics activities (hula-hoop = 73%HRmax and jogging = 80%HRmax). By contrast, we also found the rowing squat ($65\pm 8\%$ HRmax) and leg extension ($68\pm 8\%$ HRmax) muscular activities varied compared to Grave's overall mean score for muscle conditioning (2010). This is likely to be accounted for in the variation in the effort of performance of the activities included. However, with the exception of jogging, our findings complement Grave's in the sense that the Wii activities fell within a low-to-moderate intensity range.

ACSM physical activity guidelines for adults recommend a minimum moderate intensity level for significant health gain. Nevertheless, it is also identified that any increase in physical activity, regardless of the intensity level is better than undertaking no exercise and will still confer health benefits to older adults (Nelson, 2007). Having said that, the results suggest some variability in the effectiveness of the type of activities, indicating that while there is potential for overall physiological benefits in using the Wii, this will not be constant for all the games. As such, there is likely to be a degree of variation in the physical intensity (and therefore associated health benefits) of the Wii Sport and Wii Fit games that warrant further investigation. In particular, as we have tried to demonstrate,

Graves et al. argues “interventions using Wii Fit should assess changes in components of fitness... muscular strength and endurance, cardiorespiratory fitness, balance, coordination, and flexibility” (p. 398).

Determining how to gauge the appropriate level of exertion rate in the gameplay gives a good reason for the need to measure heart rate feedback, which could be incorporated through an appropriate sensor device to ensure that users are working at an intensity required for health benefit. Recent research with pedometers using steps per minute as a measure of exertion has shown this to be a useful method of monitoring and promoting activity at sufficient intensity levels for health benefit (Johnston et al. 2006). By including body sensors, like a heart rate monitor or appropriate accelerometers, it is feasible that physical intensity of the exercises could be visually monitored with feedback to indicate if the user is required to work at a lower or higher intensity to achieve their overall training goals. Although this facility is not currently available on the Wii Fit and Wii Sports programmes, heart rate monitors are provided by gaming vendors like EA Sports, for a range of exergame applications². Incorporating better mechanisms to guide users in the level of effort required to obtain and manage cardiovascular activity, whilst utilizing the system to automatically adjust exercise intensity, and trigger suitable instructions and safety mechanisms when dangerously over performing, is applicable to our target group. However, ensuring that the gameplay matches the physiology of the individual, by determining a slow heart rate compared to not putting in enough physical effort is computationally very challenging (Stach et al. 2009).

Findings from this study suggest that in addition to heart rate, using RPE to assess exertion level is also appropriate. Mean RPE values in relation to heart rate readings during the activities were comparable; participants were generally able to gauge perceived exertion well in comparison to actual exertion (heart rate). Working above 12 on the RPE scale corresponds to the intensity required for physiological adaptation. Hula-hoop, jogging and leg extension fell into this category. ACSM guidelines recommend that during resistance exercise heart rate should not be used to assess intensity level (ACSM 2006). Therefore for the muscular exercises RPE may be a better indicator of intensity.

² <http://www.ea.com/games/ea-sports-active-2>

Rowing squat was of a moderate intensity based on heart rate data, but mean RPE scores were less than 12 (the minimum RPE score for physiological adaptation).

1.4.4 Mood and cognitive effects

An immediate favourable effect of playing the Wii on mood was found. Mood improved pre- to post-session shown by PANASpos scores increasing, and PANASneg scores decreasing from pre- to post-Wii sessions. Similarly, physical activity has been shown elsewhere to have immediate positive effects on mood in older people (Pierce and Pate 1994; King et al. 2009).

In contrast, the Wii session had no significant effect on cognitive function assessed using the TONI-IQ score and trail B test time, however time to complete the TONI-IQ test was longer before using the Wii than after. This could be due to an increase in alertness and a quicker response time to the questions asked. Speculatively, other explanations could be that participants had a better understanding of the test, and therefore spent less time thinking about what they had to do (e.g. a 'practice' effect), or that they simply felt tired and gave less thought time towards each response (TONI-IQ duration lasted up to 26 minutes, with the total testing session lasted approximately 120 minutes). As such, it is inconclusive whether the improvements in time to complete the TONI-IQ were due to the physical activity, a combination of both, or another factor such as a practice effect. Similarly, there is good indication that to determine the effects of physical activity on cognitive function, exercise programs need to be repetitively completed for a much longer time period. According to Erickson and Kramer (2009), aerobic training programs of over six months long have demonstrated measurable and beneficial impacts on cognition. Program duration, frequency and length are therefore critical factors requiring further consideration.

1.4.5 Objective three: appropriateness of Nintendo Wii for older adults

Overall the participants in this study perceived the Nintendo Wii was as an appropriate physical activity tool for older adults. Participants enjoyed the activities they undertook and were able to use and interact with the interface relatively well. The only criticism was for the force plate, both for safety reasons and for being insensitive to movements made. Possibly alternative forms of monitoring movement (e.g. limb accelerometers) would be more suitable with this age group. Many of the

participants in this study perceived that the Nintendo Wii programme would be useful for others in their age group, particularly those who are housebound or in poor health, rather than themselves. The physical activity levels of this study sample illustrated that they were a very physically active group and probably had regular physical activity habits. Overall views may have been different with a less active group. Recent studies have examined the Nintendo Wii as an affordable tool for rehabilitation, e.g. for stroke patients (Saposnik et al, 2010)

Sustaining long term adherence of any physical activity programme is challenging. Previous research has reported that fifty percent of people who begin an exercise programme will drop out within six months (Weinberg & Gould, 2003). In this study over half of the participants said that they would use the Wii again. The majority of research so far has focused on the acute or short term effect of using exergames. Exploring the longer term use of the Wii and strategies within the interface to enhance adherence would be an interesting and useful area of further study.

1.4.6 Study limitations

It is important to emphasize that this was an exploratory study. Nevertheless, some improvements need to be made for future research. For example, heart rate intensity was measured using %HRmax rather than the ideal method of indirect calorimetry (a 'gold standard' for measuring exercise intensity). Similarly, heart rate could have been elevated as a result of trying to learn new and unfamiliar tasks, which could have resulted in greater heart rate being recorded (and an over-estimation of intensity) – compared to games being played in a home setting, where the individual is more familiar with the Wii exercises undertaken.

Another limitation was the lack of a control group to compare the immediate effects of the exergaming on cognition and mood. Namely a group that came to the same testing site but undertook a sedentary task (for example, watching TV or playing another type of computer game, rather than using the Wii). Thus, the positive immediate changes in mood cannot be conclusively attributed to the Wii session alone and therefore should be interpreted with some degree of caution. In addition, the order of the activities was not randomised and the duration of the overall session not standardised and may have had an effect on participant's effort and effect of the session. Participants were told that mood and cognitive function were being assessed to determine if there were any effects on these

outcomes from taking part in the research session. Thus, it cannot be excluded that the improvements in mood were due to taking part in the research rather than the gameplay. For the trail test and TONI-IQ, a practice effect is also plausible. In order to reduce this effect, valid parallel tests were used. Study sessions were also conducted during working hours. Time of day may therefore have indirectly affected mood and performance in the cognitive tests and the physical activities, especially if participants had their session immediately after a day of work.

In addition, on the whole the study group was reasonably active, with the majority of individuals reporting that they participated in exercise, either for personal gains or social interaction. Whilst this does not present a constraint of the study given our target user group, it is clear that less active and/or less healthy participants would likely find the activities more challenging and intense. As a result, there is some justification for reviewing this set of exercises with more sedentary adults, particularly older and frailer age groups.

1.5 Conclusion

The findings of this study suggest that the Wii is worthy of further exploration as a physical activity tool in adults aged 55 years and above. Wii Fit hula-hoop, jogging, rowing squat and leg extension activities were all of an appropriate intensity to gain significant benefits in health. Alternatively, we found the other games corresponded to a light intensity. Suggested design features include visual feedback on heart rate or rate of perceived exertion while using the Wii to ensure that the user is working at their desired intensity and at a level required for health benefit. A positive effect was found on mood, but due to the lack of a control group it cannot be concluded if this was due to the Wii session or another factor.

Intervention trials are now required to determine the effects of using the Wii as a repeated exposure on health and on programme adherence to support the endorsement of exergames, such as by the Department of Health in the UK for the Wii Plus game. Positively, there is evidence that interactive video game exercise programmes may have better adherence over the short-term (e.g. 6 weeks) than traditional exercise programmes (Warburton et al. 2007). In addition home-based physical activity interventions have been shown to have better adherence in older adults than community-based

interventions (King et al. 2000), with some indication that mid-older aged adults prefer to exercise at home rather than in an exercise class (Wilcox et al. 1999). Nevertheless, without the conduction of a longitudinal intervention study, the use of exergames to increase and maintain physical activity levels and the resultant effects on health will remain unclear.

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Appendix A: *Cardiorespiratory intensity category in relation to heart rate (% of predicted maximum heart rate) and Rate of Perceived Exertion (RPE).*

| Intensity category | Heart rate | RPE rating |
|---------------------------|-------------------|-------------------|
| Very Light | <50%HRmax | |
| Light | 50-63%HRmax | 6-11 |
| Moderate | 64-76%HRmax | 12-14 |
| Vigorous | 77-93%HRmax | ≥15 |
| Very hard | ≥94%HRmax | |
| Maximal | 100%HRmax | |

Appendix B: Usability questionnaire



- This questionnaire will examine your views on using the Nintendo Wii / Wii Fit.
- Your feedback is very important to us so please answer the questions as truthfully as possible.
- Please be assured that complete confidentiality will be kept at all times and at no point will you be identified.
- If you give consent you will have the opportunity to discuss further any points raised from this questionnaire during the interviews.

1) On a scale of 1-5 (1 being not good, 5 being excellent) rate your enjoyment of the following activities:

- | | | | |
|-----------------------|--------------------------|--------------|--------------------------|
| ▪ Step aerobics | <input type="checkbox"/> | Jogging | <input type="checkbox"/> |
| ▪ Warm –up stretching | <input type="checkbox"/> | Torso twists | <input type="checkbox"/> |
| ▪ Bowling | <input type="checkbox"/> | Yoga | <input type="checkbox"/> |
| ▪ Hula – hoop | <input type="checkbox"/> | Flexibility | <input type="checkbox"/> |

2) On a scale of 1-5 rate the following in order of how difficult you found the following activities: (1 being easiest, 8 being most difficult)

- | | | | |
|-----------------------|--------------------------|--------------|--------------------------|
| ▪ Step aerobics | <input type="checkbox"/> | Jogging | <input type="checkbox"/> |
| ▪ Warm –up stretching | <input type="checkbox"/> | Torso twists | <input type="checkbox"/> |
| ▪ Bowling | <input type="checkbox"/> | Yoga | <input type="checkbox"/> |
| ▪ Hula – hoop | <input type="checkbox"/> | Flexibility | <input type="checkbox"/> |

3) How easy or hard was the hand remote to hold in terms of size and weight? (Please tick one box)

Easy

Satisfactory

Hard

4) How easy or hard was the hand remote to use in terms of navigating around the screen? (Please tick one box)

Easy to use Satisfactory Hard

5) How easy or hard was the balance board to use? (Please tick one box)

Easy to use Satisfactory Hard

6) How would you prefer to receive the instructions during the activities?

- Written instruction alone
- Spoken instruction alone
- Demonstration alone
- Combination of written and spoken instruction
- Combination of written instruction and demonstration
- Combination of spoken instruction and demonstration

7) Please tick the box that best describes the amount of written and spoken instructions given during the games and exercises?

- Not enough instruction
- Just the right amount of instruction
- Too much instruction

8) How would you prefer to receive the instructions before/after and between the activities?

- Written instruction alone
- Spoken instruction alone

- Demonstration alone
- Combination of written and spoken instruction
- Combination of written instruction and demonstration
- Combination of spoken instruction and demonstration

9) Tick the box that best describes the written and spoken instructions given before/after and between the games and exercises?

- Not enough instructions
- Just the right amount of instructions
- Too many instructions

10) In terms of the instructor: (please tick one box from each section)

a)

- I would prefer to have a virtual instructor of a similar age to me
- I would prefer to have a virtual instructor of a younger age to me
- I would prefer to have a virtual instructor of an older age to me
- The age of the instructor did not bother me

b)

- I would prefer a instructor of the same sex to me
- I would prefer a instructor of a different sex to me
- The sex of the instructor does not bother me

**10) Did you think the exercises and games were appropriate for someone your age?
(tick appropriate)**

Yes

No

Uncertain

11) Do you think you would use this device to exercise at home if you had one? (tick appropriate)

- Yes
- No
- Maybe

Thank You for taking the time to complete this.

If you have any further comments please use the space below

Appendix C: Topic guide for semi-structured interviews



Topic 1: Computer use and physical activity history

- ❖ Do you have a computer at home and do they use it? Explore thoughts towards computers? (If given instructions would you use one)?
- ❖ Do you watch TV? How much and how they feel about this.
- ❖ Have you ever used video games in the past? Explore feelings towards.
- ❖ Do you think you do enough physical activity? Explore what they do and feelings towards physical activity.
- ❖ What do they think about the use of computers to get/stay active?

Topic 2: Device session

- ❖ Which device/s did you use? Thoughts on the session/s? Why?
- ❖ What exercises did you find difficult/easy and why?
- ❖ What exercises did you enjoy/dislike and why?
- ❖ Were there any types of exercises missing that you think are important/would have liked? Why?
- ❖ Were there any types of exercises that you thought should not have been included? Why?

Topic 3: Device usability

- ❖ How did you feel using the device? What were the good/bad points?
- ❖ What did you think of the remote/(force plate –Wii only)?
- ❖ Would you use this device at home? Do you think you would stick to using it? Do you need someone else to play alongside?

Topic 4: Programme design

- ❖ Instructor (old/young, fit/unfit, male/female)
- ❖ Background music
- ❖ Colour schemes
- ❖ Instructions (quality, quantity) – clear what you were meant to do?
- ❖ Movement between games/exercise

