Retraining function in people with Parkinson’s disease using the Microsoft kinect: game design and pilot testing

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Abstract

Background: Computer based gaming systems, such as the Microsoft Kinect (Kinect), can facilitate complex task practice, enhance sensory feedback and action observation in novel, relevant and motivating modes of exercise which can be difficult to achieve with standard physiotherapy for people with Parkinson’s disease (PD). However, there is a current need for safe, feasible and effective exercise games that are appropriate for PD rehabilitation. The aims of this study were to i) develop a computer game to rehabilitate dynamic postural control for people with PD using the Kinect; and ii) pilot test the game’s safety and feasibility in a group of people with PD.

Methods: A rehabilitation game aimed at training dynamic postural control was developed through an iterative process with input from a design workshop of people with PD. The game trains dynamic postural control through multi-directional reaching and stepping tasks, with increasing complexity across 12 levels of difficulty. Nine people with PD pilot tested the game for one session. Participant feedback to identify issues relating to safety and feasibility were collected using semi-structured interviews.

Results: Participants reported that they felt safe whilst playing the game. In addition, there were no adverse events whilst playing. In general, the participants stated that they enjoyed the game and seven of the nine participants said they could imagine themselves using the game at home, especially if they felt it would improve their balance. The Flow State Scale indicated participants were immersed in the gameplay and enjoyed the experience. However, some participants reported that they found it difficult to discriminate between different types and orientations of visual objects in the game and some also had difficulty with the stepping tasks, especially when performed at the same time as the reaching tasks.

Conclusion: Computer-based rehabilitation games using the Kinect are safe and feasible for people with PD although intervention trials are needed to test their safety, feasibility and efficacy in the home.

Keywords: Parkinson’s disease, Kinect, Rehabilitation, Balance, Exergaming

Introduction

Parkinson’s disease (PD) is a multi-system neurodegenerative disorder that impairs postural control and mobility, impacting negatively on community ambulation [1] and increases the risk of slips, trips and falls [2]. Exercise is emerging as an effective therapy to improve gait, balance and mobility in PD [3,4]. Furthermore, it appears that the mode of delivery and content of exercise is important for the optimal long-term change in functional activities and this is thought to be due to more effective retraining of compensatory circuits within the brain [5]. Practice of complex tasks (total body movement rather than exercising a single joint), using sound and vision to enhance exercise, increased practice and knowledge of changes in performance have all been shown to be important features of exercise [5-13]. It is difficult to achieve this with standard physiotherapy and the intensity and opportunities to engage in PD specific exercise...
programs are limited due to access to physiotherapy services. Exercise-based computer games (exergames) such as those played with the Nintendo Wii™, Sony PlayStation Eye™ and Microsoft Kinect (Kinect) systems may help facilitate high volume and quality exercise to improve postural control and mobility in people with PD in the home. These systems may also be used as sensors to measure clinically relevant outcomes during gameplay [14].

Initial studies have produced promising results for the use of exergaming as a rehabilitation tool for older adults and people with neuropathies [15-23], including those with PD [24-29]. The current literature on exergaming for PD suggests that people with PD accept and enjoy playing exergames, are able to improve their gameplay with practice and that improvements in gameplay transfer to improvements in clinical measures of postural control [24-29]. However, there is little evidence in regard to its safety and its clinical effectiveness is yet to be established by large randomised clinical trials. In addition, all but one of these previous studies used commercially available games which are not specifically designed for PD. To our knowledge, there have been no exergames developed to improve postural control in people with PD. Therefore, we set out to design an exergame to improve the dynamic postural control of people with PD using the Kinect system.

The Kinect system is a camera-based controller which a player can use to directly control a game through body movement without the need for balance boards or handheld controllers. Another benefit of using the Kinect system is that its depth sensor allows measurement of three-dimensional movement patterns, which allows real-time feedback of movement whilst playing the game as well as home-based assessment of clinical outcomes and symptoms. Three dimensional reconstruction of body motion also permits the development of games that target specific coordination patterns when retraining movement, unlike other controller or force platform based exergaming systems. This feature may be useful to enhance the quality of training as well as help avoid injury or fatigue due to poor technique.

The specific aims of this project were to i) develop a simple game for retraining balance and postural control for PD, with input from people with PD and physiotherapists with expertise in PD; and ii) pilot test the prototype game with a group of people with PD to assess the game’s safety and feasibility.

Part 1 - game design
Both computer games and exercise interventions need to be acceptable for the intended population [25,30]. Taking a user-centred design approach, we conducted a design workshop with people with PD to input into our game design to ensure the game was appropriate for people with PD.

Methods
Participants
Two people with mild to moderate (Hoehn & Yahr stage II and III) PD and one carer attended the design workshop. Parkinson’s disease support groups were contacted through a national PD charity, Parkinson’s UK. People with PD were included if they were between 40–80 years old and had mild to moderate PD. The design workshop consisted of one three-hour session. Participants took part in a discussion about the accessibility and usability of commercially available exergames (Nintendo Wii™ and Microsoft Xbox Kinect) and exercise based computer games for people with PD. Participants were then provided the opportunity to play and view several types of games and comment on their appropriateness for people with PD. Finally, they were asked to discuss their thoughts on which features they would like included in a game targeting their postural control. We also asked participants about their daily use of technology and preferences for the style and type of game they would like us to develop. The session was video recorded and transcribed for inductive thematic qualitative analysis. Ethical approval was obtained from the Newcastle University Research Ethics Committee and all participants signed an informed consent form prior to this study.

Results
Design workshop
Several requirements relevant to game design emerged from comments made during the design workshop (Table 1).

When observing our participants with PD play different types of games, we noted that one person had marked difficulty using the Nintendo Wii Fit™ balance board.

Table 1 Participant comments during the design workshop

| Concerns | Did not like the idea of an adventure or complex narrative based game, especially science fiction |
|----------|------------------------------------------------------------------------------------------------|
|          | Were concerned that the pace of the game should not be too fast |

| Preferences | Preferred the idea of solo play over play with others (self-conscious over performance) |
|-------------|------------------------------------------------------------------------------------------------|
|             | Seemed more attracted to ‘real life’ events than complex characterisation or fantasy elements |
|             | Expressed a preference for cartoon style graphics over more realistic renderings |
|             | Liked puzzles, although one participant expressed concern that combining puzzles with physical tasks might be overly complicated |
|             | Expressed a preference for outdoor scenarios; |
|             | Were able to identify with a cartoon avatar which mirrored their actions |
|             | Enjoyed satisfying sound effects associated with actions (for example, the thwack of hitting a ball when playing a golfing game) |

Eye™
board, which he had to repeatedly step on as part of a commercial dancing game. Two of the participants also found using the handheld Nintendo Wii™ controller frustrating when playing a golf game.

**Game design**

Based on design requirements established through interactions with people with PD and an iterative design and development process between the research team's physiotherapists, game designers and artists, a prototype game targeting postural control rehabilitation in people with PD was created. Microsoft’s research ‘Kinect for Windows SDK (software development kit)’ was used to provide an Application Programmer’s Interface to the Kinect sensor. The game was developed to train postural control by rewarding high volumes of reaching outside of the base of

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**Figure 1** Conceptual game artwork based on the suggestions from the design workshop (Panel A) and an annotated screenshot of the final game highlighting important game features (Panel B).
support and taking large multi-directional steps. Early sketches of game artwork and an annotated screenshot of gameplay are shown in Figure 1 (See Additional file 1: Video 1 for an example of gameplay). The premise of the game was that players took on the role of a farmer picking fruit from a tractor, a theme inspired by one of the design workshop participants. As the tractor moved through the environment, players had to reach out to pick fruit and drive (by stepping) to avoid obstacles.

To ensure people with PD did not initially find the game too complex, we structured the game with 12 levels of increasing complexity. Training of postural stability was informed by a theoretical model of balance dysfunction and focussed on three of the four domains: quiet stance, reactive postural adjustments and anticipatory postural adjustments [31]. The early levels of the game focussed solely on reaching (anticipatory adjustments), and introduced more cognitively challenging levels (reactive adjustments) whereby the hand with which the player picked the fruit was conditional on the type and colour of the fruit (i.e. "Pick the red apples with your left hand and the yellow pears with your right hand"). In doing so, the game promoted moving the centre of mass from quiet standing to outside the base of support. As the players progressed, they were required to drive the tractor to avoid oncoming obstacles such as sheep, high wires, birds and wasps. The tractor was driven by making large steps either forwards (tractor moves up), backwards (tractor moves down) and sideways. Promoting large steps was aimed at targeting hypokinetic movement demonstrated by people with PD, which is responsive to external cueing [32]. One foot had to stay in the centre of the tractor to ensure people took large steps instead of several small steps as well as to restrict the player’s movement within the capture volume of the Kinect sensor. In addition to hearing a positive noise for successfully collecting fruit (relatively high pitch), a bar at the side of the screen filled up to indicate better collection of the fruit throughout each level. At the end of each level, an encouraging noise (“crowd cheering”) played and the proportion of fruit successfully collected was displayed.

People with PD also often have difficulties performing motor tasks when dual-tasking [33,34]. Therefore, the final levels of the game were designed to train postural control under dual-task conditions, by requiring players to both pick fruit (reaching) whilst driving the tractor to avoid the obstacles (stepping) concurrently. The multi-directional stepping combined with reaching tasks further stimulated postural control under more dynamic conditions than just reaching alone. To ensure the game speed was appropriate the speed of the game could be manually adjusted by either the player or clinician and automatically slowed down if the player repeatedly missed fruit or collided with obstacles. Conversely, and the game became faster if the player successfully collected the fruit.

Part 2 – safety and feasibility of gameplay
After the design phase, we sought to pilot test the game with a group of people with PD to assess its safety and feasibility, as well as obtain feedback about the gameplay. For the purposes of this article, we define safety as the ability to maintain postural control whilst playing the game, without slipping, tripping or falling. Feasibility was defined as the ability to play and improve gameplay performance, as well as the enjoyment and immersion in the gameplay.

Methods
Participants
Nine people with PD were recruited through local movement disorder clinics to play the game. Inclusion criteria: diagnosis of idiopathic PD (by a consultant neurologist with a specialist interest in movement disorders), absence of any other neurological problem or any severe co-morbidity likely to affect gait, absence of dementia, adequate sight and hearing with glasses or hearing aid if required, independently mobile indoors without a walking aid and no severe dyskinesias or prolonged off periods. Participants were tested at the peak dose of their anti-Parkinson’s medication.

Demographic and clinical measures
Prior to gameplay, we documented participant age, sex, height and body mass. In addition, we measured motor disability using part III of the Movement Disorders Society version of the UPDRS (Unified Parkinson’s Disease Rating Scale) [35] and balance self-efficacy using the Activities-specific Balance Confidence scale [36].

Setting and equipment
We wished to pilot test the game in a controlled laboratory setting to ensure its safety prior to testing its effectiveness in the home. To achieve this, participants attended the Movement Laboratory at the Clinical Ageing Research Unit, Newcastle University, to play the game. The game was displayed on a 1080x780 resolution LG plasma screen (1100 mm wide × 620 mm high), mounted 3 m away from the participant. We played the game through a laptop running Windows 7 to which the Kinect sensor was attached. The Kinect API’s skeletal tracking functions provided a position estimate for 20 anatomical measurements (including the head, shoulders, elbows, wrists, hands, hips, knees, ankles and feet) at a frequency of 30 Hz.
Participants played the game for approximately 30 minutes. The game was presented with increasing levels of difficulty (Table 2). Participants were allowed to keep playing or to repeat levels if they wanted. We ceased level progression when participants were tired or if the levels were too complex for them to keep progressing. Unlike an intervention trial where the progression may be slower, allowing for more practice to master each level, the goal of this session was to expose participants to as much of the game’s content within the session, without pushing them to levels which either they or the researchers perceived as too cognitively or physically demanding. Each level lasted approximately 2 minutes, and participants were encouraged to comment and discuss the gameplay, highlighting things they liked or disliked. An experienced physiotherapist was present at each session to ensure the safety of the participant.

**Data extraction and synthesis**

Gameplay data was recorded while participants played the game, including their body position which was recorded using the inbuilt Kinect skeletal model tracker. We also recorded the number of times participants reached for fruit or stepped to avoid obstacles as well as if these attempts were successful. All of the participants who progressed through all of the levels repeated Level 5 (stepping sideways and conditional reaching for fruit) to assess whether their gameplay improved with practice (i.e. successfully gathered more fruit per level). Data are described using means and ranges.

**Interview process**

A semi-structured interview was conducted by the research physiotherapist after the gameplay. Questions focused on perceptions of playing the game in terms of safety, gameplay, the game’s utility as an exercise intervention and the type of games participants already play at home. Interview questions are listed in Table 3. Participants were also asked to fill in a Flow State Scale questionnaire, which quantifies different perceptual domains of immersion during physical activity (See Table 4 for example items) [37].

**Results**

The participants had mild to moderately severe PD (Table 5). Seven of the participants played games at home, with most of them playing paper based puzzles such as Sudoku or crosswords (Table 6). Three of the participants played the Nintendo Wii™ at home. Most participants were self-motivated to exercise and all stated they exercised at least once a week (Table 7). Walking was the most common type of exercise mentioned. Most people played games and exercised by themselves, although some did involve friends or family.
There were no adverse events although one participant felt dizzy prior to gameplay due to hypotension. Six of the participants progressed through all of the levels of the game, with the remaining three finding the more demanding levels (multi-directional stepping whilst reaching for fruit) too demanding. Whilst playing the game, participants performed a mean of 328 reaching actions (range 167–628 repetitions) and 167 large steps (in multiple directions, range 74–276 repetitions). People performed worse (percentage of fruit successfully gathered per level) on levels where they had to concentrate which hand to pick the fruit with compared to levels where fruit could be picked with either hand (Figure 2).

**Participant feedback**

Table 8 summarises participant feedback relating to gameplay. Generally participants reported enjoyment of playing the game and all of the PD participants felt safe whilst playing the game. Seven of the participants stated that they could imagine themselves playing the game at home, although whether or not they would buy the game would depend on the price. Participants said they would enjoy playing the game with others, with competition being an important gameplay factor raised by several people.

Negative feedback of the gameplay focussed on problems with the visuals, such as the inability to distinguish different objects in the game, such as the birds and the wasps, or the position of the fruit coming towards them. Some people also had some difficulty with stepping to drive the tractor. Interestingly, many perceived the game as more of a cognitive challenge than as a game of balance.

**Flow state scale**

The results from the Flow State Scale (Table 5) questionnaire, which quantifies the levels of immersion into the gameplay, showed that the participants experienced states of flow occurring during the game. This was particularly the case with respect to the “concentration” item which showed the highest mean value across participants, indicating that all participants were concentrating a lot on the game. Participants also tended to score highly on the loss of self-consciousness, clear goals and enjoyment items.

**Discussion**

**Game design**

The first aim of this study was to create an exergame appropriate for people with PD. Exergaming may provide clinicians with an effective therapeutic tool to augment rehabilitation of motor function [38,39] in people with neuropathies such as traumatic brain injury [15,40], cerebral palsy [16,41] and stroke [20,23]. However, it is important that the rehabilitation exergames are designed within the context of the specific rehabilitation needs and capabilities, as well as fitting with the values and lifestyles, of the target population.
suggests that the game was able to challenge motor
when they could pick the fruit with either hand. This
trate on which hand to pick the fruit with compared to
performed worse on levels where they had to concen-
trate more on the later levels of the game. For example, we found participants
inconveniently demanding. For example, we found participants
subjectively made the later levels of the game more cog-
demanding. To this end, we
based intervention, however, we would suggest people
play as we could within one session of playing. In a home-
site, we sought to expose participants to as much of the game-
progress. Alternatively, programming thresholds of per-
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PD vary greatly between people and over the progression of
the disease. One important consideration is that the games
for people with PD should not be made too difficult, in
terms of their pace or cognitive complexity [25,27]. This
concern was also raised in the design workshop and feed-
back on gameplay in the current study suggested that, al-
though the pace was not a problem, some people found
aspects of the game more cognitively than physically chal-
lenging. For example, not all of the participants were able
to progress through all of the levels of difficulty on the first
attempt playing the game, as they found the later levels too
complex. In most cases, the aspect of the game participants
found most challenging was producing the correct stepping
direction in relation to oncoming obstacles under the time
pressure of the game. This is understandable considering
we sought to expose participants to as much of the game-
play as we could within one session of playing. In a home-
based intervention, however, we would suggest people
progress slowly through the levels, stopping to practice
each component of the game until they felt confident to
progress. Alternatively, programming thresholds of per-
formance required before progressing to harder levels may
help ensure safety and appropriate practice during home
based gameplay.

Another goal of the game was to train postural control
under cognitively challenging situations. To this end, we
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gress through the game is paced in such a way that
someone playing at home would not progress too fast
and risk their safety.

In addition, many of our participants found some visual
aspects of the game difficult, whether that be distinguishing
the different types of obstacles, the timing of
when they had to reach for the approaching fruit or recog-
ising the different positions of the tractor. Im-
paired visual function has been well described in Parkin-
son’s disease but its impact on movement is less clear
[42-47]. The visual difficulties observed in this study are
interesting for two reasons. First, it highlights the need
to make the appearance of visual assets in exergames for
PD easy to distinguish and their orientation more obvi-
ous, as not to distract from the primary challenge of the
game which is to improve movement. Second, it is pos-
sible that exergames might be useful in identifying and
monitoring visuospatial problems in PD.

Overall, the feedback from the pilot testing was positive
however we also asked participants to provide construct-
ive feedback to help us identify issues where the game can
be improved. We hope that these issues raised may also
help other developers produce games appropriate for
people with PD. For example, better distinction between
game objects, better visual cues as to the timing of ap-
proaching objects, a more intuitive driving mechanism
and more positive feedback may improve the acceptance
of the game. Music and multi-player compatibility may
also improve gameplay and enjoyment of the game. In
addition, some participants did not feel they would play
the game at home if available. Of these, one participant felt

Table 6 Response to interview questions about games played at home

| Participant | What types of games do you play at home? | Who do you play with? | How often do you play and for how long? | Where in your home do you play? |
|-------------|------------------------------------------|-----------------------|----------------------------------------|--------------------------------|
| 1           | Does not play games                      | -                     | -                                      | -                              |
| 2           | Crosswords, polygon, Sudoku, code word   | Mainly on my own, although occasionally with partner | 1 hr per day | Kitchen, Bedroom or bathroom |
| 3           | Crosswords, sometimes pub quizzes         | Crosswords alone. Pub quizzes with friends. | 4 x 1 hr per week but more when travelling | Living room, Public transport |
| 4           | Sudoku, Crosswords, Brainteasers, Solitaire, Scrabble, Nintendo Wii | Alone or with daughters | Paper-based games (30 min-1 hr per day) Nintendo Wii (1 x 20 min per week) | Paper based puzzles (Bedroom), Nintendo Wii (lounge) |
| 5           | Sudoku                                    | Myself                | Once per week                          | Kitchen                        |
| 6           | Solitaire, Back gammon, bridge, chess, checkers | With partner or grandchildren | 5 x up to 1 hr (plus 10 min at work) | Home office                    |
| 7           | Nintendo Wii, Sudoku, crosswords, pub quiz, checkers, chess, bridge | Alone or occasionally with family | Rarely on the Nintendo Wii Monthly pub quiz Sudoku and crosswords daily | Spare bedroom, Pub |
| 8           | Nintendo Wii, various card games, jigsaw puzzles, Sudoku, puzzle books | Friends, mother, daughter, grandchildren | Varies greatly depending who is visiting Monthly friends games night Nintendo Wii 1 x week | Bedroom, lounge, dining room |
| 9           | Does not play games                      | -                     | -                                      | -                              |

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PD vary greatly between people and over the progression of
the disease. One important consideration is that the games
for people with PD should not be made too difficult, in
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addition, some participants did not feel they would play
the game at home if available. Of these, one participant felt
the game was too easy, one said the graphics and gameplay would need to be at the standard of commercial games for him to play with his grandchildren, or felt they'd get bored too quickly. A third participant did not respond well to DVD-based exercises previously and was apprehensive about investing the time into playing the game if she was not convinced it would improve her performance.

**Safety**

All nine of the participants responded that they felt safe whilst playing the game and there were no adverse events during any of the sessions. The physiotherapist attending the sessions, however, noticed that some participants had some difficulties during the stepping tasks. This was most notable when having to step backwards and when under time pressure during more complex levels of gameplay.

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Table 7 Response to interview questions about exercise

| Participant | What type of exercise do you do/How often? | Do you exercise with anyone? | Are you self-motivated to exercise? | Would you consider the game you just played an exercise game? | Did the game support the right type of exercise for you? |
|-------------|--------------------------------------------|-----------------------------|-------------------------------------|-------------------------------------------------------------|----------------------------------------------------|
| 1           | Walking (1/2 mile daily)                    | No. Occasionally with partner | Yes                                 | Not really                                                 | It was too easy                                   |
| 2           | Horse riding (3 x per week) and stable care (daily), Pilates/physiotherapy exercises (30 min daily), Walk the dog (daily), Gardening (30 min weekly) | Friends, daughter or employee (stable care) | Yes                                 | Yes                                                        | It probably was because it made me exercise my arms and shoulders. |
| 3           | Walking. Used to enjoy pilates and yoga (3 x weekly) but have stopped 6 weeks ago because of hypotension | In a group | Was self-motivated before problems with hypotension | Yes                                                        | I think this is a good balance exercise but feel it would not suit me now because of my hypotension. |
| 4           | Yoga (3 x weekly). Aerobic and strength training once weekly. Walk daily. | No. Occasionally with partner. | Yes, mostly.                       | Yes. It was also cognitively challenging. It's not like any other physical exercise. It made me use my mind and body. | Yes. I need to be encouraged to do more. Slow movements can be off-putting but the movements in the game were right for me and didn't trigger my tremor. |
| 5           | Incidental exercise (works on a farm daily). Otherwise no. | No. Although it my children were younger I would feel more motivated to pay with them. | No.                             | No. It was more a mind exercise. I thought I was thinking more than moving my body. | No. If I thought my balance was poor and this game would help it, I would definitely play this game at home. |
| 6           | Walks 1 mile daily.                           | No.                             | Yes                                 | No. I thought it was more of a game of coordination, reaction time and balance. | Not for me.                                      |
| 7           | Walking 3 x weekly                            | With my partner.                | Yes but not enough to go to the gym. | No. It's not aerobic enough to be considered an exercise. | Yes. It challenges my balance and coordination. |
| 8           | Walk about 6,000 steps daily. Circuit exercise class at the gym once weekly. Nintendo Wii once weekly. | I usually exercise alone but sometimes with others. | Yes                                 | Yes. Quite energetic and I felt I used my arms and legs a lot. | I thought this game challenged my coordination but felt that my balance was not challenged enough. |
| 9           | Golf twice weekly.                            | Yes.                             | Yes                                 | An exercise of the mind. | I'm not sure. I found the game challenging. |
| 10          | Walking (1/2 mile daily)                      | No. Occasionally with partner    | Yes                                 | Yes. Not really                                            | It was too easy                                   |
Feasibility

Participants in this study tended to enjoy playing the game and also improved with practice. Results for the Flow State Scale indicated that people with PD were immersed in the gameplay. These findings in the context of the motor learning literature suggest that exergaming
could be a potent intervention to improve function in PD. Motor learning studies demonstrate capacity for people with PD to learn a variety of motor tasks ranging from upper limb movement to whole-body functional tasks [6,48,49]. The use of complex task practice rather than repetition of a simple movement has been shown to produce a more pronounced alteration in the neural circuitry suggesting cortical reorganization [5]. A common feature of these studies is the use of enhanced sensory feedback such as auditory pacing cues, visual cues or somatosensory cues to provide augmented feedback about movement performance. Motor learning is enhanced by external cueing [7,8] and action observation [9] whilst clinical studies have shown that externally cued practice over more extended periods (3–6 weeks) leads to significant benefits for gait, balance and transfers [6,10–12] and is more effective than interventions that do not use augmented feedback [6,12,13,50]. These studies represent an exciting and novel area of development that could have potentially important benefits for functional independence. Exergaming represents a way to deliver relevant and motivating training modes that capture all of the above elements of complex skill practice of a wide variety of skills coupled with enhanced sensory feedback are still to be developed.

Home use and tailored training may also facilitate exercise compliance and motivation [51]. Compliance is enhanced as computer games are becoming a normal leisure activity for older adults with the benefits of family and carer participation, and they focus on recreation rather than rehabilitation. Encouragingly, most of the participants in the current study incorporated playing games at home into their leisure time, with three of them already using a Nintendo Wii, and most could imagine themselves using the game at home. Furthermore, exergames are usually designed for home use allowing self-management and monitoring of exercise based therapy. The only home-based exergaming study in PD showed that 18 × 40 minute sessions of playing Nintendo Wii® fitness based games over 6 weeks was able to elicit improvements in several clinical measures of motor function (such as the 10 m walk and unipedal stance) in a small sample of people with PD [26]. More needs to be known about the compliance and effectiveness of home-based exergaming in PD before widespread adoption as a rehabilitation tool. Despite the promising results in this lab based study, it also remains unclear whether exergaming is safe in a home-based setting for people with PD.

This study was limited in so far as we were not able to establish whether it is as effective at improving postural control, nor how it compares to traditional rehabilitation programs. The small and relatively high functioning sample in our study also limits our ability to generalise to the broader population of people with PD. As older adults also show reduced mobility [52] and dual-task deficit in dynamic postural conditions [53], this game may help improve postural control in older adults without PD as well.

Conclusion
Exergaming using the Microsoft Xbox Kinect system is safe and feasible for people with PD to use however future home-based intervention studies with a larger sample are required to establish our game’s safety, feasibility and clinical efficacy as a home-based intervention to improve the postural control of people with PD.

Additional file

Additional file 1: Video of example of gameplay.

Competing interest
The authors declare that they have no competing interest.

Authors’ contributions
All authors contributed to the design and implementation of the study. RM, MW and MB designed and ran the design workshop and analyzed the data to elicit design requirements. DJ and GS developed the game which was designed based on input from all authors. GB, DM and BG were responsible for data collection and processing of the pilot testing data. PO and LR provided important intellectual input to the manuscript. All the authors contributed to the revision of the manuscript and approved the final version for publication.

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