Final Report for project RBT 1141:

Designing serious games for enhancing physical function and social interactivity in older adults.

Background

Over recent years, the development of low-cost motion-based video games has revolutionised the gaming industry. Whereas previous games relied primarily on fine manual movements, more recent 'active' games (such as Nintendo Wii products) require large energetic movements, such as emulating the movement of a ski-jump. Several studies have evaluated the potential benefits of using these active games in a rehabilitation context (e.g., training balance in older adults) (Goble et al., 2014). On the surface, this seems like an intuitive way to exploit the physical nature of these games. However, currently available commercial games are designed primarily for a young audience, which leads to several problems. First, the games contain complex, fast-moving graphics and scoring systems that are difficult for older adults to follow. This could be due to a general unfamiliarity with modern computer game mechanics, but also possible age-related cognitive deficits. Second, the nature of the tasks and user interactions are not designed to train aspects of balance associated with fall-risk in older adults (Young et al., 2011). Third, the physical requirements of the games are often too great for older adults to be successful in the task, leading to reduced motivation to participate (Young et al, 2011). The purpose of the current project was to evaluate a novel balance training game that attempted to account for each of these issues in various ways.

The PONG game

The first computer game ever made was called PONG. In this game, players move a paddle to intercept a ball (see Fig. 1). If you miss the ball you lose a life. In the original PONG game, players moved the paddle by manually pressing a key. However, by intercepting the signal from a Nintendo Wii Balance Board and linking it to virtual reality software (Young et al., 2011) it became possible to design a replica of the PONG game where players used their balance to control the paddle movement. The most attractive aspect of PONG (aside from the simple graphics and scoring system) was the nature of the task. One aspects of balance that is closely associated with fall-risk in older adults is declining 'Limits of Stability'; a reduction in the extent to which someone can move their balance in a given direction without falling over (Duncan et al., 1990). In the PONG game, players must intercept the ball in a range of positions up to, including, and sometimes beyond their limits of stability. Therefore, we predicted that playing this game would provide a way to train this specific aspect of balance.

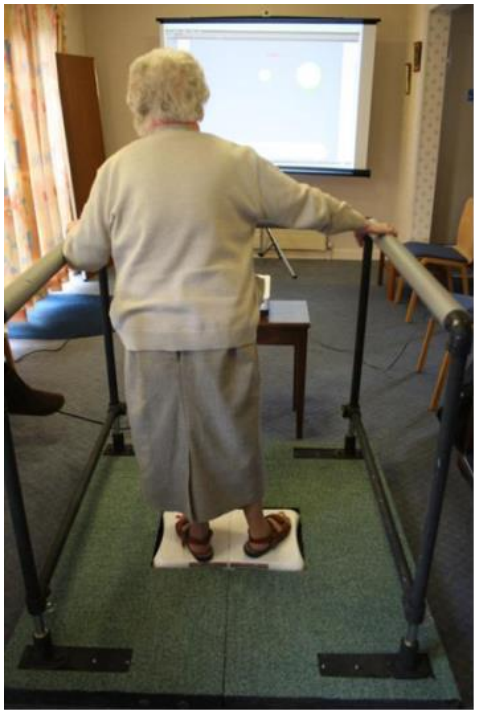

Figure 1. Red arrows show the direction in which players will move their 'paddle' in an attempt to hit the moving target.

Modifying the PONG game

Unpublished data from Young et al. (2011) showed that many older adults who experienced significant problems with their balance expressed a wish to stop playing single player active games due to the impression that they were 'not good enough to join in'. This was in spite of the fact that their balance was significantly improving as a result of playing the games. We made two major adjustments to the PONG game in an attempt to counteract these negative self-appraisals.

First, we created a handicapping system whereby each participant's score in a clinical test of functional balance (Berg Balance Scale) was directly proportional to the size of the paddle they were assigned within the game. Second, we created software that allowed two Wii Balance Boards to be connected to the gaming software at the same time. Consequently, participants in the current study could play a single player game against the computer, or a multi-player game against a real-life opponent. With the handicapping system in place, players could compete against each other on an 'even playing field' (i.e., each player had an approximately equal chance of winning regardless of balance ability). An important aspect of playing a multiplayer game is that task success is not exclusively dependent on one's own performance, as it also relies on the performance of your adversary. Therefore, when players lose in a multi-player game they may be less inclined to attribute failure to their own personal shortcomings, which in turn may avoid associated decline in balance confidence and motivation to participate. Therefore, we predicted that following multi-player gaming sessions players would report increased confidence and motivation to participate, compared to when playing single-player games. We also predicted that players would choose to play for longer periods during multi-player sessions and would choose multi-player games in the future.

Method

Twenty six older adults (>65 years) were recruited to the study from four sheltered residential accommodation schemes in West London. Participants from each scheme were assigned to one of two groups (A or B – see Table 1). The group name determined the order in which participants from each scheme played the single- and multi-player games. Participants played the games in 2-3 sessions per week within each phase of testing. This took place in the communal living area within each scheme.

	Baseline (2 Weeks)	Phase 1 (2 Weeks)	Phase 2 (2 Weeks)	Retention (2 Weeks)
Group A	No Gameplay	Single-player	Multi-player	No Gameplay
Group B	No Gameplay	Multi-player	Single-player	No Gameplay

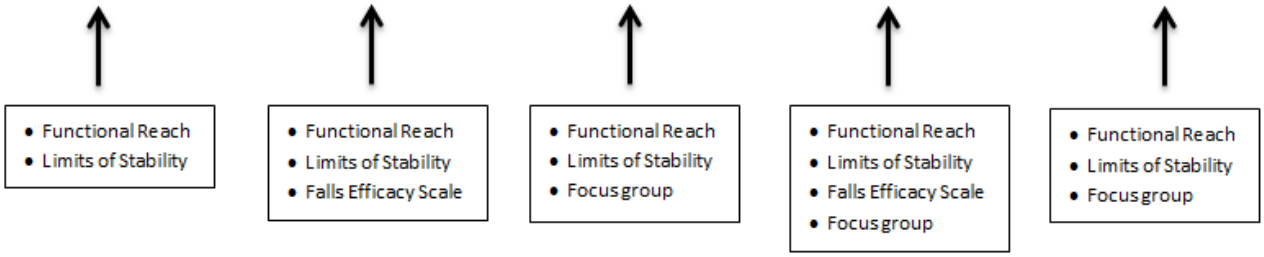

Table 1. *The various phases of the study protocol with details of repeated measurements*

During each phase of testing we measured the duration of each participant's game play. Before and after each session we also took two measures of participant's functional balance: 1) Limits of stability (the distance a participant can move their balance in an anterior-posterior direction, recorded using the Wii Balance Board); 2) Function Reach (the distance a participant can manually reach forward along a tape measure when starting from a neutral standing position) (Duncan et al., 1990).

Focus Group Methodology

For Phases 1 and 2, focus groups occurred directly after the final gaming session within each phase, and lasted approximately 30 minutes each. With each participant taking part in three focus groups after Phases 1, 2 and Retention, we ensured that members of each group were kept consistent between sessions. This was done to stabilize the social environment, helping to stimulate a continued discussion about how the group experienced the games within the different phases. All focus groups were audio recorded and transcribed verbatim. In this study an inductive approach was adopted as analysis was driven by the data, as opposed to trying to fit data into a pre-existing coding frame, or the researcher's preconceptions (Willig, 2013).

Following transcription, a 'generation of initial codes' was completed for each focus group transcript. Analysis was conducted across the whole data set (across testing phases and groups) so that full consideration could be given to repeated patterns within the data. Codes were used to summarize and synthesize what is happening in the data alongside identifying semantic content. The codes were then organised into groups through a process of clustering

and re-clustering which allowed themes to develop; themes that were subsequently discarded if not supported by the data. To ensure anonymity, each participant was assigned a random participant number (e.g., P7).

Amendments to original proposal

Participants commented on the high level of commitment required to complete the study. Due to the high number of gaming sessions and repeated balance tests, participants were clearly unhappy with the inclusion of repeated questionnaires. In an attempt to avoid unnecessary participant attrition un-related to game-play, and to keep sessions light-hearted and focussed on the gaming, the following questionnaires were removed from the protocol and the focus group topic guide was expanded to include core aspects of each questionnaire: Exercise Motivations Inventory, general Health Questionnaire, Occupational Style Attribution questionnaire, and the Social Function Questionnaire.

Results

Functional balance measures

Twenty six older adults were recruited to the study. Participants played for longer durations (approximately double) and more frequently in multi- compared to single-player sessions (see focus group data for further descriptions). However, there was no change in functional balance or balance confidence that related to the single- or multi-player gaming.

Participants did not report any significant change in balance confidence (as measured by the Falls Efficacy Scale) after Phase 1, 2 or retention compared to baseline. However, repeated-measures ANOVA showed that when pooling data from Groups A and B, participants did show a remarkable improvement in both Functional Reach ($F_{(3,51)} = 19.5$ $p < 0.01$) and Anterior-Posterior Limits of Stability ($F_{(3,51)} = 5.74$ $p < 0.05$) (see Fig. 2).

Importantly, Medio-Lateral Limits of Stability showed no significant changes across testing phases. With all participants only playing anterior-posterior sway games (see Fig. 1), this finding is relevant as it demonstrates that improvements in functional balance (see Fig. 2) were not a consequence of participants becoming familiar with the testing procedures, and instead represent a genuine improvement in functional balance ability specific to the movements involved in gameplay.

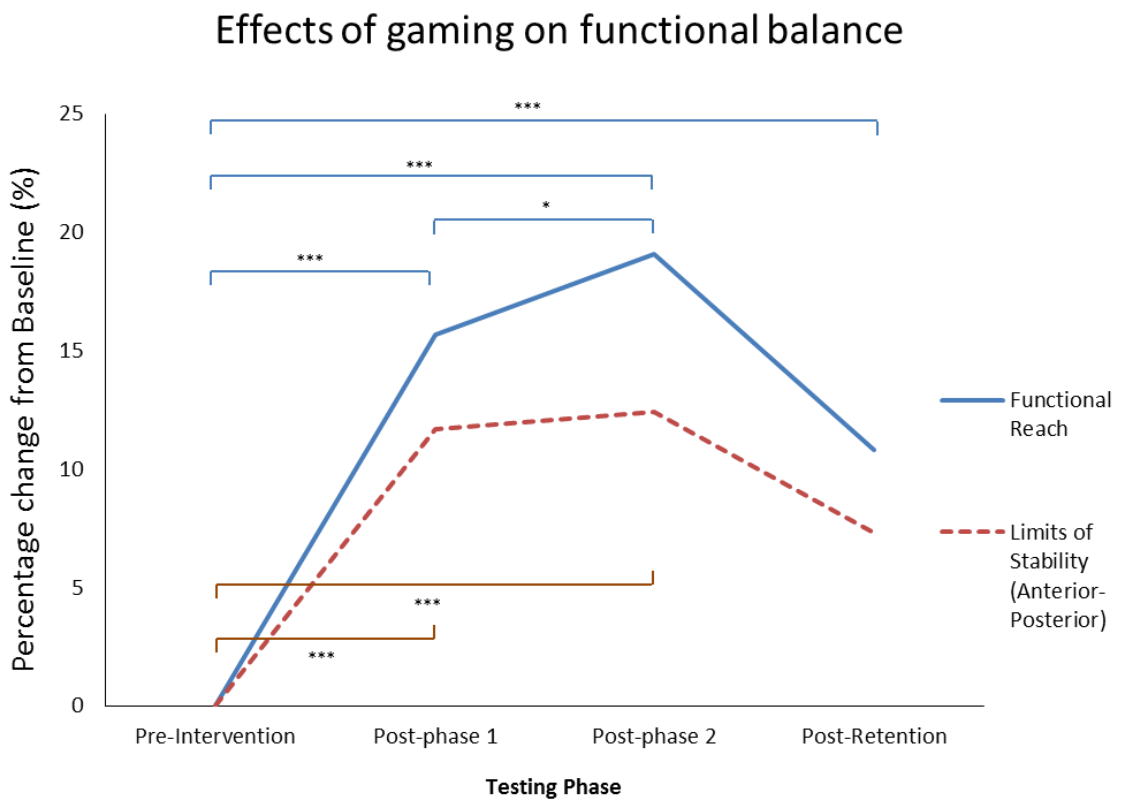

Figure 2. *The line graph represents the percentage change in balance function relative to pre-gaming baseline measures recorded. * $p < .01$, *** $p < .001$.*

In summary, gameplay was clearly successful in improving balance. However, multi-player participation did not appear to accelerate the rate of improvements or significantly influence general balance confidence. The following section describes output from the focus group sessions where we evaluated participant's perceived changes in balance ability and opinions regarding various aspects of the game.

Focus group data

Perceived changes in balance ability

From the entire cohort, 9 participants recognised that their balance had improved as a result of playing the games. The most pronounced benefit was experienced by P3 who recalled the numerous benefits she had experienced as a result of engaging in the gaming sessions stating "I'm a recycled teenager". P3 had started using a 3-wheeled walker around the scheme due to experiencing hip pain that affected her mobility. However in the focus group following Phase 2 she independently walked over to the common room without her walker or stick due to reduced hip and back pain for the first time in several months. P3 then spoke of an increased ability to lean on her heels and toes; movements that she could not do previously. When speaking about this change P3 then demonstrated how she could sit to stand independently from her chair (without using the arms of the chair) and described how when she first started the sessions she "couldn't do anything like that".

P5 reported a reduction in aches and pains, which made doing things in terms of her daily activities “a bit easier” reporting: “I do think they have done your legs good in the sense that when you’re walking about and doing things you’re not getting any aches or pains in your knees and your ankles”. P18 also talked about how, for years she would “fall backwards when getting out of bed”. However, a by the end of Phase 2 she claimed that these near falls had stopped and said “I don’t even think about it now, so it [the game] must be doing something right”.

In contrast to the results from the Falls Efficacy Scale, the majority of participants claimed to have increased various aspects of their confidence as a result of playing the games. For example, P5 spoke about having “more confidence in the way I move”. However, these comments did not often refer to improvements in general balance confidence, but rather an improved recognition of one’s abilities and limitations. P1 said that playing the games made her “a bit more sensible”. P4 agreed “I’ve learned not to rush into everything”. P18 said “It’s made me more aware of being careful if you know what I mean. I might have bent down to do something whereas I think now can I do that or am I going to fall over”. P5 spoke about how “youngsters can just get on with it” but that she had to learn to concentrate about her movements, and that she had not realised how bad her balance was in some aspects.

Interestingly, in spite of the remarkable improvements in balance function (see Fig 2) several participants were unaware that their balance had improved (P3, P5, P6, P10, P18, P19, P21). P8 said “I have not improved….I got worse”. P3 replied “no you haven’t you were bloomin good against me just now”. P1: “no you were good [P3 name]…you got better”. We suggest that this negative self-appraisal is a likely consequence of the game design. Unlike commercial Wii games, the PONG game was designed to train aspects of balance that often decline with increased age and are associated with fall-risk. While the difficulty of the game was adapted to suit the abilities of each individual (using the handicapping system), the nature of the task (leaning forwards and backwards to the limits of stability) was inherently uncomfortable and served to highlight weaknesses in participants’ balance. Therefore, while balance function clearly improved, participants became increasingly aware of certain frailties. This finding has significant implications for the future design of balance training games for older adults. For example, Butler et al (2014) showed that older adults who are not aware of balance deficits (and subsequently adopt ‘risky’ behaviours) are significantly more likely to fall in the following 12 months. It is possible that, through participation in carefully designed active games like ours, older adults might gain more accurate insight into their ‘action-capabilities’ and be less likely to take risks with their balance in future.

Single-player vs Multi-player

All Participants highlighted a preference for the multi-player sessions due to the competitive and challenging element. P18 described how in the multi-player game "the ball came back the same but you had the rivalry". P20 agreed "yeah it’s no good beating yourself up". P14 commented: “It increases the intensity of your application of playing…by playing another person you know the rivalry”. Some participants discussed how they enjoyed the multi-player games more because they were competitive people, exemplified by P5 reminiscing about

when she beat P2 for the first time “ah [P2 name], i wanted to thrash him, that was good”. P6 also talked about her intention to play for longer and do secret practice sessions “wouldn’t it be great if I got better and be good enough to beat you with a smaller paddle”. These data suggest that the direct rivalry and interpersonal challenges that emerged through repeated multi-player sessions served to enhance each participant’s engagement. However, this rivalry did not emerge to the same extent in single-player sessions, even though players were still competing against each other on a leader board containing player’s recent scores.

This intensity of application was further supported by other participants who spoke of trying harder in the multiplayer so they could ‘beat others’ (P1, P2, P5, P13, P17, P18). This increased the social interactivity between participants during game play itself and ‘the challenge’ was a key motivational factor for future attendance. It was interesting that some participants (P2, P7, P14) felt they would not attend future gaming sessions without a researcher being present to set up equipment and organise the session. However, the majority of participants suggested that the competitive and social element to the multi-player games would motivate them to attend in future, but that this would not necessarily be the case if the only option was a single-player game.

Social function and Daily routines

The majority of participants did not consider the gaming to have directly impacted on their daily activities or social function. These individuals were exclusively those who claimed to already be reasonably active. In contrast, P3, P7, P9 and P19 were clear exceptions to this rule describing a clear change in their routine. P9 reported “she likes it more because it gets her out of her room”. P7 said “I never feel like that sort of person who needs people around them to sit and chat. I like to come out of my room for a purpose. This is a good purpose”. P19 describe how “I used to shut myself away. Now I try to come out every day”. P19 described how grateful he was to the other participants for the social interaction: “I’ve started a jazz group, just listening to music like, to give something back”. The success of the gaming sessions in promoting social interactivity was undoubtedly a consequence of the serious purpose of the game (i.e., to improve balance). Without it, several participants would not have attended even a single session. However, once in attendance, the serious aspect of the game was rarely mentioned and it was the social interactivity and interpersonal rivalry that were of greatest importance to all concerned.

Summary and dissemination of results

Results from the current study will form two journal articles (currently in preparation). First, the original concept of the PONG game and associated handicapping system will be submitted to the journal Gait & Posture. This paper outlines the significant clinical relevance of measuring participant’s movements during gameplay. We suggest that this information might be used as a tool for diagnosing fall-risk and identifying tailored rehabilitation strategies.

The second article will be submitted to the Journal of Gerontology, and will describe the remarkable improvements in functional balance achieved through playing the PONG game.

This article will describe how, whilst general balance confidence was not altered through game play, the majority of participants did describe being more aware of their limitations since playing the game. This publication will also document players' resounding preference for the multi-player game, due to the interpersonal rivalries that emerged.

The various results of the project were presented by W.Young, T.Ellmers and A.Cocks (Ellmers and Cocks were researchers affiliated with the project) at international conferences in June 2015: (North American Society for the Psychology of Sport and Physical Activity) (Young) and July 2015: The congress for the International Society for Posture and Gait Research (ISPGR) (Young, Ellmers and Cocks). These presentations received significant attention and led to an invitation for W.Young to co-organise a conference on active gaming in 2016 (affiliated with ISPGR). The current results will also be publicised through the Games for Health Europe consortium and Gerontoludic Society in 2016. This publicity has already led to new collaborations with games designers at the University of Hong Kong and Stanford University. The purpose of these collaborations is to establish guidelines for the development of active games specifically for training balance in older adults, and those with neurological disorders such as Parkinson's disease.

References

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