# BASE - An Interactive Technology Solution to Deliver Balance and Strength Exercises to Older Adults

Julie Doyle, *Cathy Bailey, Ben Dromey
TRIL Centre
University College Dublin, Ireland
*National University of Ireland, Galway
Julie.doyle@ucd.ie, cathy.bailey@nuigalway.ie, ben.dromey@gmail.com

Cliodhna Ni Scanaill
Intel Digital Health
Intel Ireland, Ireland
Cliodhna.Ni.Scanaill@intel.com

*Abstract*— **There is a high prevalence of falls in older adults. It has been recognised that a highly challenging balance and strength retraining program can reduce the incidence of falls significantly. This paper describes the design and initial evaluation of a home-based interactive technology solution to deliver a personalised, physiotherapist prescribed exercise program to older adults. We adopted a user centred design process to ensure such technology is easy to use, acting as a facilitator to completing the exercise program, rather than an inhibitor. Initial usability findings, in addition to participant attitudes towards such a system, are outlined.**

***Keywords- Older adults, falls, interactive exercise program, design, evaluation***

## I. INTRODUCTION

Whilst a majority of older adults can live independently and enjoy a reasonable quality of life, there is a high prevalence of falls. Within the context of an ageing demography [1], the proportion of community dwelling adults who sustain at least one fall over a 1-year period, ranges from 28–35% in the ≥65 year age group to 32–42% in the ≥75 year age group, with 15% of older people falling at least twice [2], [3]. Within Ireland, the study site, falls are the leading cause of injury related visits to emergency departments. It has been estimated that whilst 80% of falls in older persons are non-injurious, the remaining 20% can have serious consequences [4]. These may include disability, mobility impairment, dependency, psychological problems, including fear of falling and social isolation [5].

Falls in older adults are attributed to a complex interaction of intrinsic and extrinsic risk factors, superimposed upon the normal ageing process, with each individual having different combinations of factors. A comprehensive Cochrane review suggests that among other factors, exercise programs that focus on at least two or more of the following: balance, strength, endurance or flexibility and home based, multi-component and individually prescribed exercise [6], may be effective falls prevention interventions [7]. Indeed, one of the most consistent, established modifiable risk factors is muscle weakness and balance impairment. A recent systematic review [8] has indicated that highly challenging training, taken in high doses (twice a week for minimum 6 months), without a walking program can reduce the incidence of falling by 42%. Traditional methods of delivery of such training have either been based in hospitals or day centres, and are delivered by qualified personnel. However, they can be costly, and may be inaccessible to geographically isolated older people.

The goal of this paper is to highlight the design considerations for developing and delivering the BASE (Balance and Strength Exercises) program to older adults through technology. This interactive, home-based technology should be intuitive and easy to use, acting as a facilitator to carrying out an exercise program, not an inhibitor. It should also motivate participants to adhere to their exercise program.

## II. RELATED WORK

Given the recent interest in motivating older adults to exercise, there has been a surge in exercise and rehabilitation technology development for this cohort, with the aim of making exercise fun and interactive. SilverFit is a system developed in the Netherlands that uses virtual reality video games to make exercising fun for older adults [9]. A 3D camera tracks users' movements and responds to them in some way. SilverFit differs from BASE in that it is an application tailored for physiotherapists, with the aim of using it in rehabilitation and fitness centres for "individual therapy, group therapy or group activity". SilverFit is typically used under supervision of a physiotherapist, who must set the difficulty of the game at the beginning of a session. In contrast, BASE is a home-based technology, with older adults in full control of its usage.

Motivating Mobility is a project aimed at developing a home-based technology solution for stroke rehabilitation, specifically helping people to reach and grasp with the shoulder, arm and fingers. The user centred design process and initial prototype development is described in [10]. This involved workshops and focus groups to understand the needs of those with stroke and the perceptions of technologies. To date, we have not come across an interactive evaluation of the system.

*Digital Object Identifier: 10.4108/ICST.PERVASIVEHEALTH2010.8881*
*http://dx.doi.org/10.4108/ICST.PERVASIVEHEALTH2010.8881*

'Wii-habilitation' has become popular in retirement homes and day care centres, whereby groups of older adults come together to play Wii, which both encourages physical exercise and social communication. Research in Singapore [11] assessed the perceptions of Wii games by older adults. The authors found that while the acceptance level was high it was necessary to convince older adults that the technology was easy to use. While Wii is certainly a beneficial means of increasing an older adult's mobility, and early research is investigating its ability to reduce falls in older adults [12], within BASE our aim is to focus specifically on improving older adults' lower limb strength and balance. To this end, we have integrated a specific, proven exercise regime for older adults – the Otago Exercise Programme is a strength and balance retraining program that has been shown to reduce falls in older adults by over a third [13]. As far as we are aware, a Wii study with older participants has yet to demonstrate an improvement in physical condition, strength or balance. Furthermore, many Wii studies take place in retirement homes or care centres. BASE is intended for deployment into peoples' homes, to increase their independence and keep them living at home for a longer period of time.

## III. BASE

Our aim is to develop a technology solution to deliver the Otago strength and balance re-training program in the homes of a number of older adults. Otago is typically administered by providing a person with a booklet of instructions on how to perform the exercises. Over a period of time, a trained instructor visits the home 5 times. Adherence is measured by asking participants to record the days they have completed the program, and the instructor makes a monthly phone call. The benefit of a technology-based solution is that it facilitates monitoring of the correct completion of each exercise, the quantity of exercises completed, and compliance to the exercise program. Prior to beginning the home deployment, the participant's physical capabilities will be objectively recorded in a clinical setting by a physiotherapist, and their in-home exercise program will be tailored accordingly.

### *A. How it Works*

The BASE in-home system, described in this paper, is a hardware and software tailored exercise system, which is installed in the homes of older adults, who are at risk of falling. The BASE in-home system uploads data to a secure central server, and updates to the exercise program can be downloaded to the BASE in-home system from the server. During the home deployment, the physiotherapist can connect to the server and remotely observe and modify the participant's exercise program using the 'Physio Console'.

The BASE in-home system consists of: 1 laptop; 1 interactive flash-based software application; 1 monitor; 1 remote control; 1 broadband connection; 2 adjustable ankle weights; 1 webcam; 3 tracking markers; 2 SHIMMER kinematic sensors (http://shimmer-research.com).

The system is started and stopped by pressing a single large button located on the front of the laptop, and the flash software automatically loads on start-up. The flash software displays the instructional content (audio and video), feedback (real-time and trend) and navigational tools, which are prescribed to each individual user.

The flash application plays video instructions for each exercise before the user performs the exercises. The Otago program consists of warm-up, static sitting and standing exercises, and dynamic walking exercises. The BASE flash application provides real-time feedback on correctness of exercise of static and dynamic exercises using animations, repetition counters and audio prompts. Correctness of the static exercises is measured by tracking (with the webcam) the location of brightly coloured markers worn on the ankles and waist. Correctness of walking exercises is measured using SHIMMER motion sensors attached to the markers. The data from the SHIMMER and coloured makers are analyzed and send to the flash application using BioMOBIUS software (www.BioMOBIUS.org). Finally, the user controls the pace of the flash application and navigates between the menus using the BASE remote control.

### *B. Initial Requirements*

Initial design requirements were gathered through multidisciplinary team workshops, whereby clinical requirements were identified and transferred to design and engineering requirements. These included:

1. The ability to provide real-time feedback as to exercise completion and target acquisition.
2. Multimodal feedback (audio and visual) to compensate for declining visual acuity and hearing impairments.
3. An intuitive input method – we decided a remote control would be the most effective input device. It should include a limited number of buttons and provide feedback as to when the button had been fully pressed.
4. Provision of trend data to participants, indicating improvements/decline in completion of exercises.

Following the identification of requirements, a prototype was developed which was refined through a number of evaluation sessions with older adults. Our main findings are discussed in the following sections.

## IV. REFINING THE DESIGN WITH OLDER ADULTS

User acceptance is critical in the uptake and continued use of any technology-based system for older adults. As one of the major goals of BASE is to encourage motivation and compliance to an exercise program, with the ultimate aim of reducing falls, it is critical that older adults are both willing and able to interact effectively with the technological program. As such, our design process involved meeting with a number of older adults to gather input on how to ensure the usability of the system, in addition to examining attitudes and beliefs surrounding both exercise and technology usage.

The aim of our first usability session was to present participants with the first version of our interactive prototype and to gather information on preferred methods of visual and audio feedback; the ability of older adults to use the remote control to navigate through on-screen button menus; the ease

Identify applicable sponsor/s here. *(sponsors)*

*Digital Object Identifier: 10.4108/ICST.PERVASIVEHEALTH2010.8881*
*http://dx.doi.org/10.4108/ICST.PERVASIVEHEALTH2010.8881*

of the setup procedure i.e. putting on markers, weights, SHIMMERs; opinions on using interactive technology to take part in an exercise program in the home; motivations to exercise and past experience with physiotherapy programs.

We initially recruited 6 participants, but unfortunately 1 was ill on the day of testing. Each participant performed a number of tasks (as described in the following subsections). During their tasks, participants were encouraged to think-aloud. Following this, participants took part in a post-task usability interview. This usability session took place in a lab-based environment within a hospital. Our second usability session involved a further 7 participants using the system in their homes. Here we focused on navigation through the system, as well as gathering more opinions on using a system such as BASE at home. These home visits also allowed the team to understand how the BASE system might fit into the participant's home and to begin to understand the challenges we might face during deployments and how these could be tackled.

### A. *Evaluating Visual and Audio Feedback*

As the user moves through each of their prescribed exercises, they receive real-time feedback regarding their target acquisition and the number of repetitions completed. At the outset of the project, it was decided to provide such feedback multimodally, i.e. through both visual and auditory channels. Multimodal feedback can compensate when one particular modality is weakened, for example, if a participant is visually impaired. However, in team workshops a number of possible designs for visual and audio feedback emerged. As such, we decided to let our end users choose which would be preferable. This occurred during our first, lab-based, usability session.

In deciding on the type of visual feedback to present to people when performing exercises, we considered four options. (1) Our physiotherapist demonstrating the exercises on screen while the participant follows along. There was a repetition counter which incremented with every repetition the participant completed. In this option there was no on-screen target (Figure 1a). (2) An abstract animation of the participant's markers on screen, with a target and a repetition counter. As the participant moved towards the target, so did the animation of the markers (Figure 1b). (3) A higher fidelity 'matchstick man' animation with an on-screen target and repetition counter. As the participant moved, the 'matchstick man' mirrored this movement until the target was crossed (Figure 1c). (4) Real-time video feedback whereby the user could see themselves on-screen as they exercised. With this option participants could see their markers overlaid on their ankles and waist on the video feedback, as well as an overlaid target and repetition counter (Figure 1d).

In order to test each of these methods of visual feedback, the user performed a task which required them to move through five of the Otago exercises. Prior to beginning, the participant was asked to put on the markers, weights and SHIMMERs. For each exercise, the participant watched a demonstration video and then completed on average 10 repetitions with each feedback method. Having completed each exercise, the participant was asked for their opinion on which feedback option they preferred in terms of aesthetics as well as how effectively it helped them to complete their tasks.

In terms of preference, the high fidelity 'matchstick man' was chosen as first preference by each participant. The real-time video feedback was least favoured as participants felt 'foolish' or 'distracted' seeing themselves on screen. In addition, the surrounding environment was visible which further distracted participants. One participant stated *"The matchstick man is really visible… you don't really want to see yourself"*. Another participant described it as *"a good clear demonstration"*.

With regard to the first feedback option, following along with the physiotherapist demonstration, all participants felt it necessary to 'keep up' with the pace as demonstrated on the screen. It was also confusing in that the repetition counter would increment with the participant's movement, and not the physiotherapist on screen. Overall, the matchstick man was deemed the clearest, most intuitive method of feedback.

The matchstick man was further developed to appear more 'life-like' than that in Figure 1. Our current design can be seen in Figure 2. The matchstick man wears markers corresponding to those that the participant wears. If the system loses tracking of the participant's markers the matchstick man's markers will disappear. This in turn forces a re-calibration whereby the participant receives the appropriate instructions. We decided to represent the participant's on-screen target as a line. We initially used circles and squares as targets but this confused participants as to whether they needed to reach the outside of the shape, or the centre. As the participant crosses the target line (which is set according to their abilities during a pre-trial assessment with the physiotherapist), the repetition counter is updated.

As a separate task to evaluating visual feedback, participants performed 2 walking exercises whereby they were asked about their preference on 2 types of audio feedback. These were a count (i.e. 'one', 'two', 'three'), and a 'ding', as the participant took a step. The audio ding was preferred by 4 of the 5 participants as it was less distracting. Audio feedback was deemed very important by all participants for the walking exercises, as they typically looked at their feet, or straight ahead whilst walking and as such could not concentrate on the on-screen visual feedback. For consistency throughout the program, we have integrated both audio (ding) and visual (repetition counter) feedback as the participant performs each of their exercises. With regard to putting on the markers, weights and SHIMMERs, participants had no problems. However, it was noted that a demonstration video would be necessary.

### B. *Evaluating Navigation*

Moving through the Flash application requires the participant to navigate using a remote control. Some of this navigation involves moving through menus to select, for example, the exercise program, exercise records and a tutorial on how to use the system. Navigation also includes moving between exercises and inputting readiness to move on. For our lab-based session we devised a navigation task whereby users

*Digital Object Identifier: 10.4108/ICST.PERVASIVEHEALTH2010.8881*
*http://dx.doi.org/10.4108/ICST.PERVASIVEHEALTH2010.8881*

were asked by the evaluator to navigate to a certain on-screen button. We logged participants' interactions in addition to observing. As participants moved between buttons, the currently selected item would enlarge. We gathered feedback following this task on the participant's perception of ease of navigation in addition to how responsive they felt the remote control was.

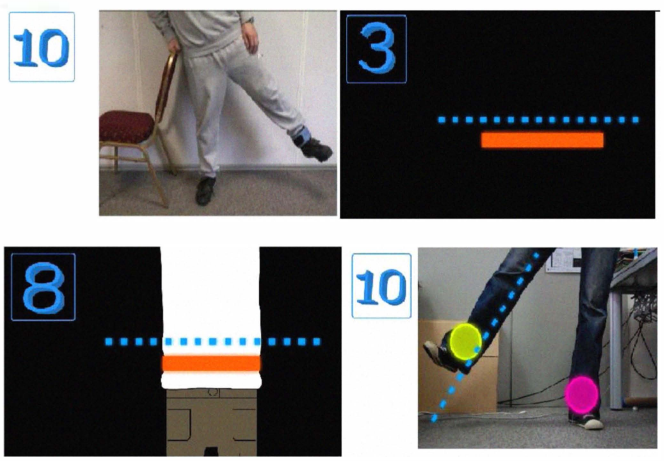


Figure 1 – Types of visual feedback evaluated (non-walking exercises)

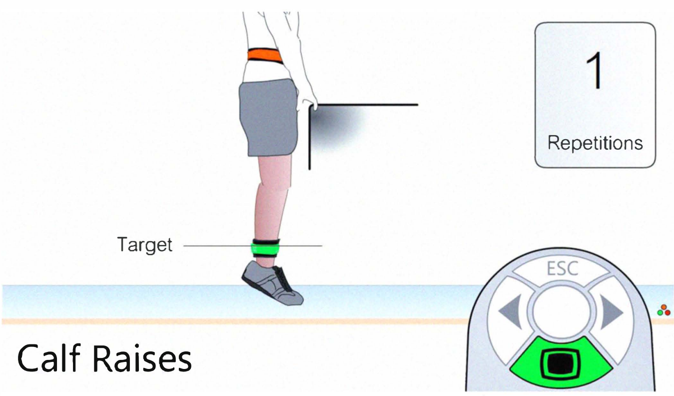


Figure 2 – Feedback screen with option to 'Pause' highlighted

Through observation and feedback we determined that we would use prompts (both visual and audio) to aid the participant in moving between menu items and exercises. Participants also highlighted the need for larger text on buttons and for the currently selected button to be more obvious. To this end we have enlarged currently-selected buttons, changed the border and added an audio message as to the description of the button that is selected.

To ease navigation from screen to screen we decided to include an on-screen visual prompt, in addition to audio prompts. Audio navigation prompts include, for example, 'Press GO to move on', 'Remember you can pause at any time'. The visual prompt can be seen in Figures 2 and 3. It is an animated graphic of the remote control. For each current state the participant is in, there are one or more new states where the participant can move on to. For example, in Figure 2, the participant can pause during exercising. This provides them with the option to resume exercising or to skip to the next exercise (if they find they cannot reach their target). In Figure 3, the participant can select the centre button to begin their exercise program. They can also use the right navigation button to move onto other menu options, i.e. to view their exercise records or to shut down the system. Within this menu, the currently selected menu item is enlarged. Furthermore, as the user moves to each option, an audio instruction is output. For example, the Shut Down option outputs 'Turn off the system', thus compensating for the visually impaired.

The remote control graphic appears on each screen, prompting the user as to how they can move on, when they can pause etc. If the system is waiting for user input before moving on, the appropriate button will slowly flash, prompting the user for input. This navigation aid was tested preliminarily during our second round of user testing in the homes. We observed no issues with participants following the on-screen prompts. However, participants said they would like to see an instructional video on how to the remote control functions, and what each button represents. This has been implemented and is played at the start of the exercise program.

### C. *Instructional Content and Controlling the Pace of the Program*

As participants completed their exercise tasks, they first watched a demonstration video on how to perform the exercise. The video played once and then moved on to the feedback screen whereby the participant exercised. In observing participants it was evident that it would be useful if the demonstration video would re-play until the participant was comfortable that they knew what to do. As such, we decided to loop all instructional videos. At the same time, we are aware that after a short period of use, participants will be very familiar with the exercises and may not need or want to watch a demonstration video. As such, these videos can be skipped. Based on these observations, we also decided the participant should have full control over the pace of the program. As such, they system always waits for user input before moving on.

We also asked participants in both sessions who they would like to see performing the demonstrations. In discussions we suggested a medical professional (physiotherapist) or an older person. This was a topic of discussion amongst the development team, with pros and cons emerging for both options. Given that the system is physio-led, it seemed obvious to have a physiotherapist demonstrate. However, there is a lot of positive research surrounding peer learning. In general, participants also saw both as positive options. There was the feeling, however, that seeing a physiotherapist would be an indication that the exercises were being demonstrated correctly. As such, we decided to go with this option.

### D. *Attitudes and Motivation to Exercise*

Motivating older adults to initiate and maintain an exercise program remains a difficult challenge. Each of the participants in our trial had undertaken a physiotherapy program in the

*Digital Object Identifier: 10.4108/ICST.PERVASIVEHEALTH2010.8881*
*http://dx.doi.org/10.4108/ICST.PERVASIVEHEALTH2010.8881*

past. The following sums up one male participant's attitude towards performing his physiotherapy exercises:
*".. At first I did them* (exercises for shoulder) *religiously… but then you sort of get browned off* (bored) *with it and you say you'll do it tomorrow.. Once you start to feel better you think you're better.. so you stop. But by then you're nearly better, you know?"*

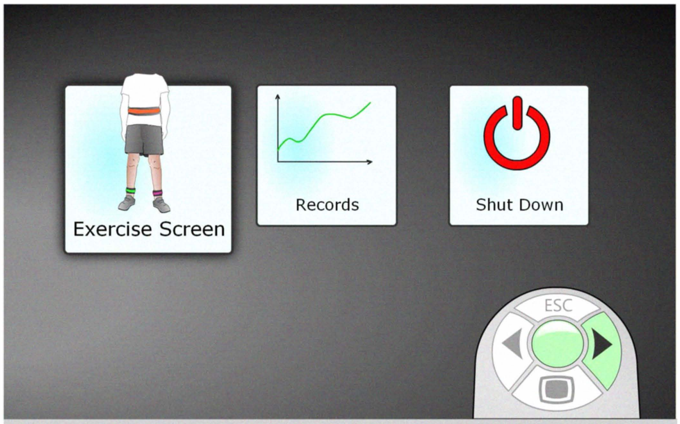

Figure 3 – Navigation Assistance

During our post-task interview we asked participants what might motivate them to comply with an exercise program over a long period of time. Three major themes emerged, the first being *health benefits.* Each of our participants had experienced a fall in the past and many were part of a fear of falling focus group that had been run by one of the authors of this paper. As such, the idea of taking part in an exercise program that specifically targets strength and balance to reduce falls was of much interest. The knowledge that the exercise program would be tailored specifically to each individual participant's needs further enhanced the perceived health benefits.

A second theme involved receiving *feedback* from the physiotherapist. This related not to real-time feedback, but progress over time. Participants felt if they could see that they were improving this would be a huge motivator to continue. Feedback was also deemed important for confidence that you were performing the exercises correctly. One female participant said:
*"I think it's so important to encourage people to do the sort of exercises that might prevent falls or give people more confidence. Sometimes it's about having the confidence to know what's safe, if you are doing the right thing, if the exercises are going to make a difference or if you are doing more harm than good. That's why feedback is so important. You can lose confidence so easily."*

Following these discussions with participants we decided to include a Records section within BASE (Figure 3), which would be updated on a weekly basis by our physiotherapist. The Records section will show the percentage of compliance to the program over the week, and a week by week view of progress such as target acquisition and the number of complete repetitions of each exercise.

Finally, the notion of being *monitored* was considered a further motivator. Participants were aware that if they were to use BASE, their physiotherapist could remotely monitor their compliance to the program.

## V. CONCLUSION AND FUTURE WORK

This paper has described the user centred design process used in developing the BASE system for older adults. Overall, participants felt confident that they could use such a system in their homes to follow an exercise program. Some important themes that emerged that required consideration in our design included the use of a high fidelity animation to provide visual feedback; the integration of multimodal feedback throughout the program; navigation prompts to facilitate moving through the program; allowing the participant to control the pace and the importance of progression reports.

The system we have designed is largely based on feedback from once off evaluation sessions with a small number of participants. We plan to deploy the system to approximately 20 older adults' homes in early 2010. As part of this deployment, we will monitor participants' usage of the system over a number of weeks, focusing on learning curve, compliance and usability of the system, when deployed into homes.

## REFERENCES


[1] Central Statistics Office, "Ageing in Ireland", 2007.

[2] M. Tinetti and C. Williams, "The effect of falls and fall injuries on functioning in community-dwelling older persons" in Journals of Gerontology Series A: Biological Sciences and Medical Sciences, Vol. 53, No. 2, 1998.

[3] J.T. Chang, S.C. Morton, L.Z. Rubenstein, W.A. Mojica, M. Maglione et al, "Interventions for the prevention of falls in older adults: systematic review and meta-analysis of randomized clinical trials", in British Medical Journal, 328, 2004, pp. 680-683.

[4] B. Gannon, E. O'Shea and E. Hudson, "Economic cost of falls and fractures among older people in Ireland", in Irish Medical Journal, vol 101, no. 6, 2008.

[5] N. Kerse, L. Flicker, JJ. Plaff et al, "Falls, depression and antidepressants in later life: a large primary care appraisal", in PLoS One, vol. 3, no. 6, 2008.

[6] C.F. Finch, L. Day, A. Donaldson, L. Segal and J.E. Harrison, "Determining policy relevant formats for the presentation of falls research evidence", in Health Policy, vol. 93, 2009, pp. 207-213.

[7] L. Gillespie, M.C. Robertson, W.J. Gillespie, S. Lamb et al, "Interventions for preventing falls in older people living in the community", in Cochrane Database of Systematic Reviews, 2009.

[8] Sherrington, C, Whitney, J.C., Lord, S.R., Herbert, R.D. et al, "Effective exercise for the prevention of falls: a systematic review and meta analysis", in JAGS, vol. 56, no. 12, 2008, pp. 2234-2243.

[9] SilverFit, accessed 15th February 2010. http://www.silverfit.nl/en/index.htm

[10] S.R. Egglestone, L. Axelrod, T. Nind et al, "A design framework for a home-based stroke rehabilitation system: identifying the key components", in Pervasive Health 2009.

[11] Y-L Theng, A.B. Dahlan, M. L. Akmal and T.Z. Myint, "An Exploratory Study on Senior Citizens' Perceptions of the Nintendo Wii: The Case of Singapore", in i-CREATe 2009.

[12] Wii-habilitation, acceseed February 15th 2009. http://www.cnn.com/2009/HEALTH/02/11/wii.fit.elderly/index.html

[13] A.J. Campbell, M.C. Robertson, M.M. Gardner et al, "Randomised control trial of a general practice programme of home based exercise to prenent falls in elderly women", in BMJ, 315, 1997, pp. 1065-1069.


*Digital Object Identifier: 10.4108/ICST.PERVASIVEHEALTH2010.8881*
*http://dx.doi.org/10.4108/ICST.PERVASIVEHEALTH2010.8881*