Building user-centred rehabilitation technologies

Assoc. Professor Lynne Baillie

Director Interactive and Trustworthy Technologies Research Group

Talk structure

1. Introduction to how we approached designing technology for rehabilitation
2. Design of the technology
3. Testing of the technology in the lab and the home
4. Trials of the technology in the home
5. Results of the trials

Our work on the project

- **envisage was a research project concerned with promoting independence by involving users in their rehabilitation through the use of visual methods**
- We needed to design and develop a rehabilitation technology for patients who were recovering from a fall and knee replacement surgery that would:
  - provide patients with suitable technological hardware that can track their exercises in the home
  - provide rehabilitation software that would provide feedback that was suitable for knee replacement and falls.

Lifelong Health & Wellbeing
Research for Healthy Ageing

HERIOT WATT UNIVERSITY

University of Strathclyde Glasgow

Team

- Falls software, Dr Stephen Uzor

- Knee Replacement software, Dr Mobolaji Ayoade

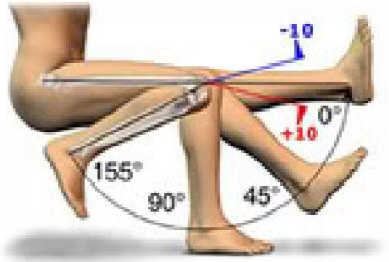
- Sensors, Dr Lee Morton

Knee Rehabilitation

- In Britain, 1 in every 20 persons over the age of 65 is affected by knee osteoarthritis
- This number is set to increase by up to 25% in a couple of decades
- Knee replacement is an effective surgical intervention for severe knee osteoarthritis (characterised by excessive pain and stiffness of the knee)
- Over 35,000 TKRs are performed each year in the UK
- An important part of the treatment is rehabilitation following knee replacement surgery.
- Research has shown that the long term success of knee replacement is highly dependent on the quantity and quality of rehabilitation received

Rehabilitation Tool Design Objectives

- To encourage correct performance



- To improve adherence

- To objectively track progress

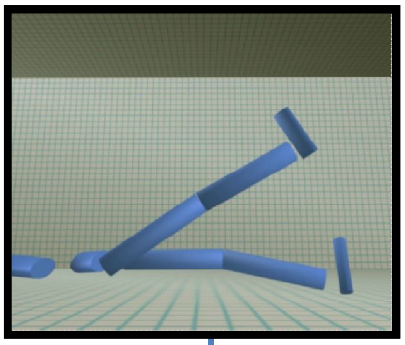
Falls

- Falls are one of the leading causes of disability in the elderly costing £2B in UK $34B USA.
- Muscle strength and balance decline with age, leading to an increased risk of falling
- Rehabilitation can improve muscle strength and balance in the lower body, thereby reducing fall risk
- However, adherence to home rehabilitation is low over long term

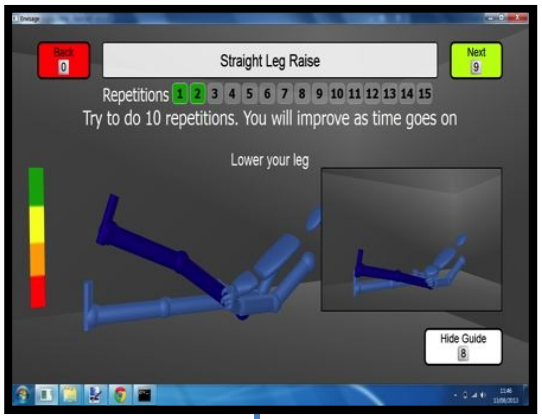
Motivation: How can we use technology to encourage long term adherence to home exercise?

Project Timeline

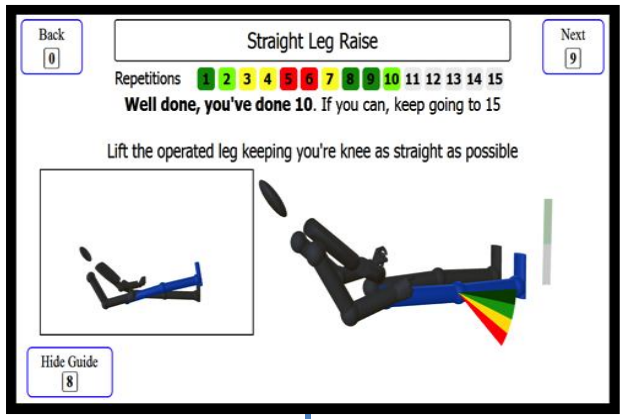
Basic Prototype



Design 1

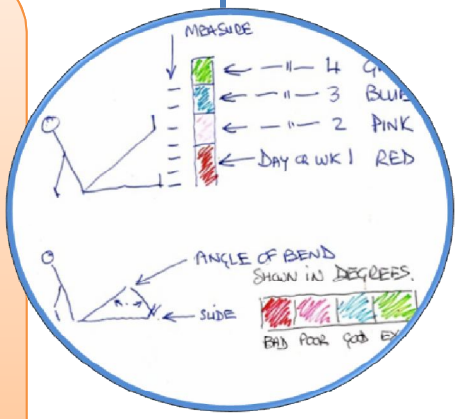


Design 2



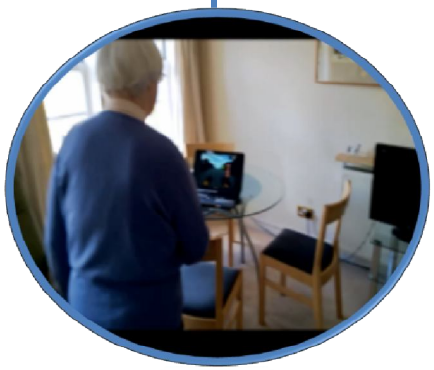
Timeline

Interviews with experts & Investigation of Technology



Design workshops

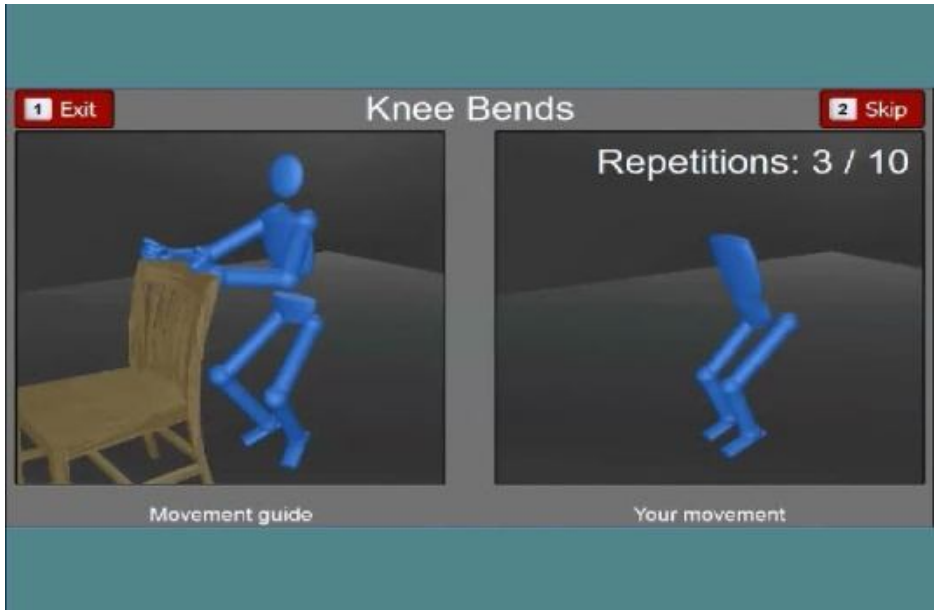
Usability studies



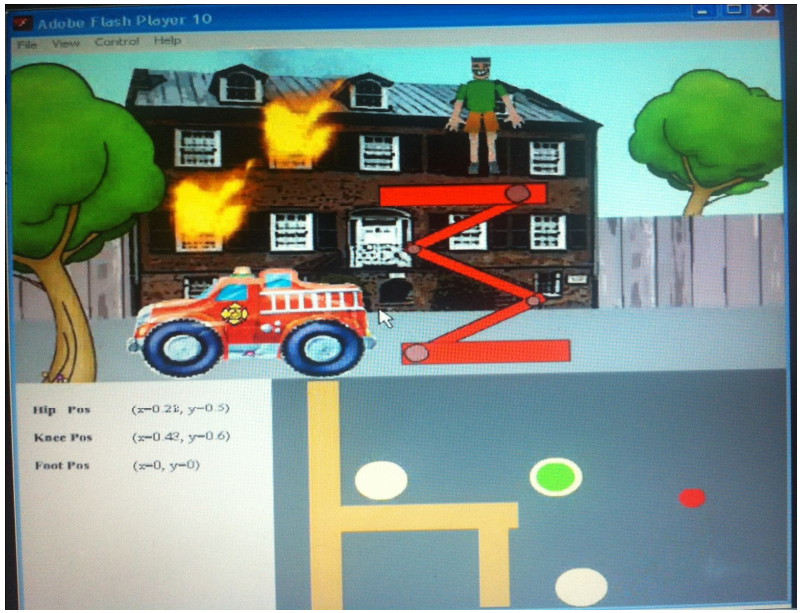
Clinical/Home studies

Falls

Visualisation



Games

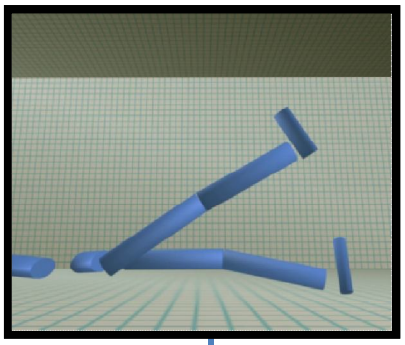


Research Questions

1. Will the use of games and visual feedback for home rehabilitation show improvements in functional recovery and quality of life when compared to current standard care?
2. What impacts will games and visual feedback have on the understanding of rehabilitation, motivation to exercise and adherence to exercise program?
3. Would the system be effective and easy to use in the home unaided for the predominantly older user
4. Can an effective video call check-up be provided to physiotherapists and patients who have undergone total knee replacement?

Project Timeline

Basic Prototype



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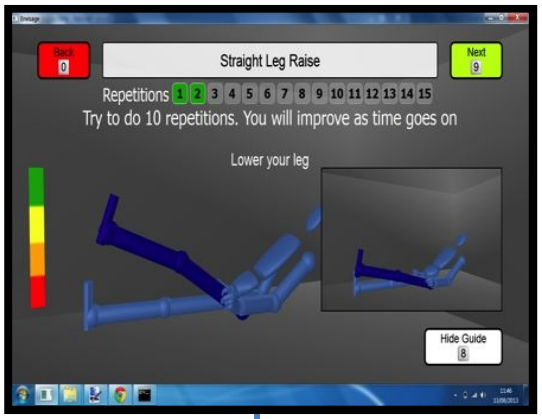
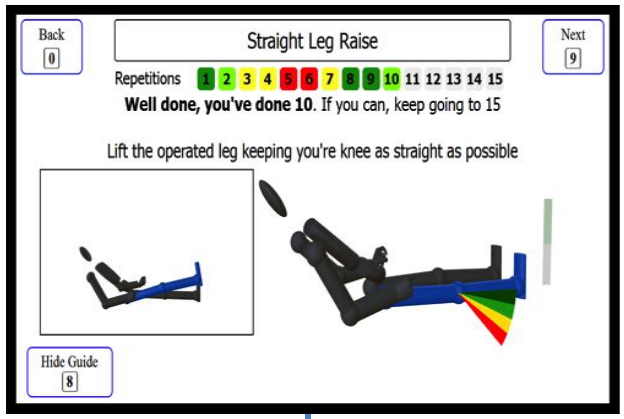
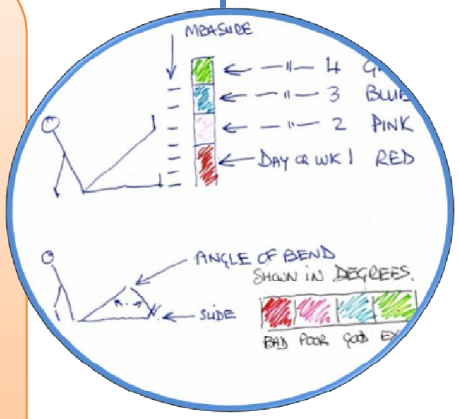


Design 2



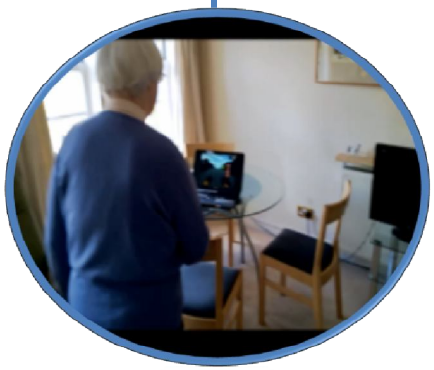
Timeline

Interviews with experts & Investigation of Technology



Design workshops

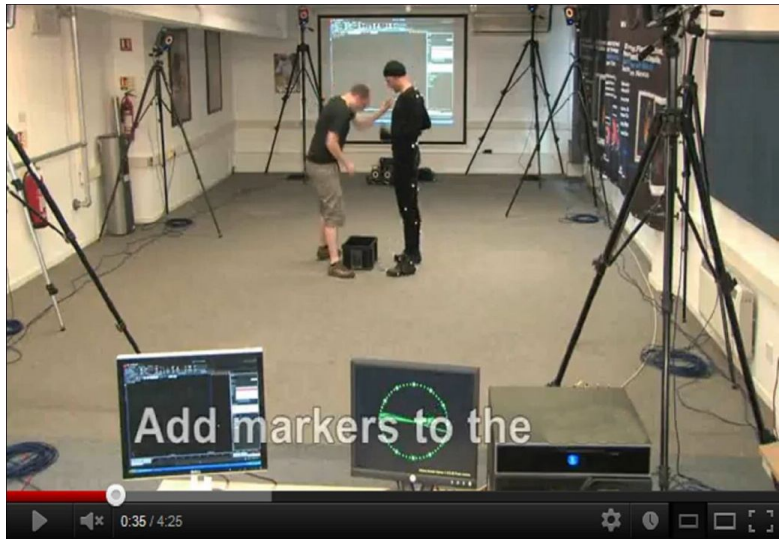
Usability studies



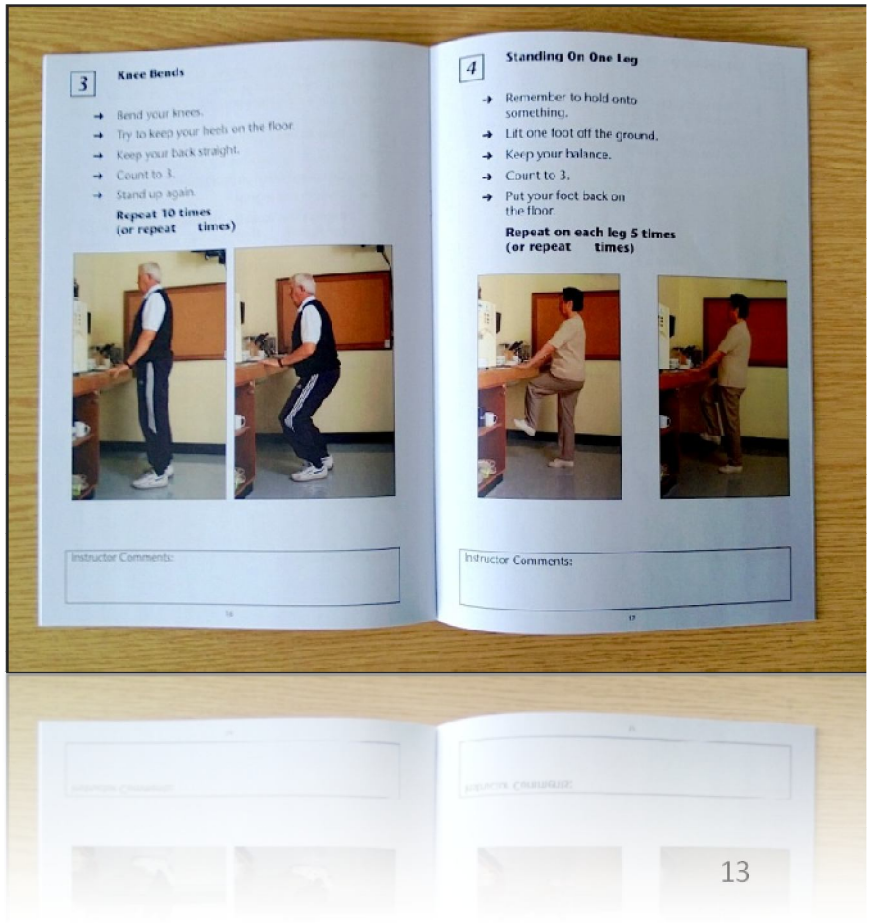
Clinical/Home studies

Designing Technology for Home Rehabilitation

- Part of the work was to figure out what were the essential elements of motion capture systems used in laboratories that we would need in the home
- Then using this knowledge & with the input of the users, make a system that would work in the home environment

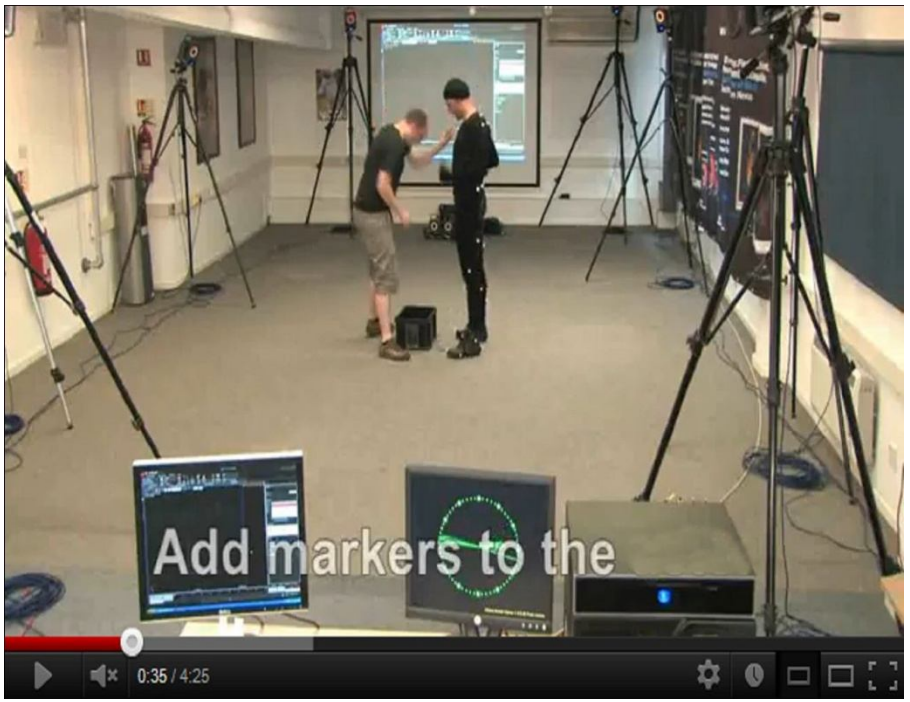


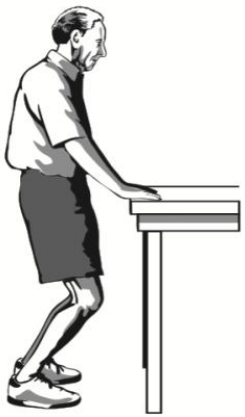
Interviews with Medical Experts about Current Care



KINECT™
for XBOX 360.

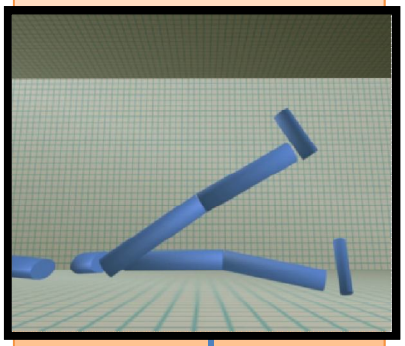
- Occlusion
- Free space
- Comfort





Project Timeline

Basic Prototype



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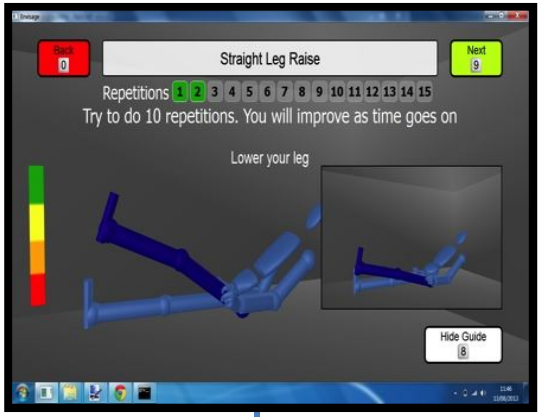
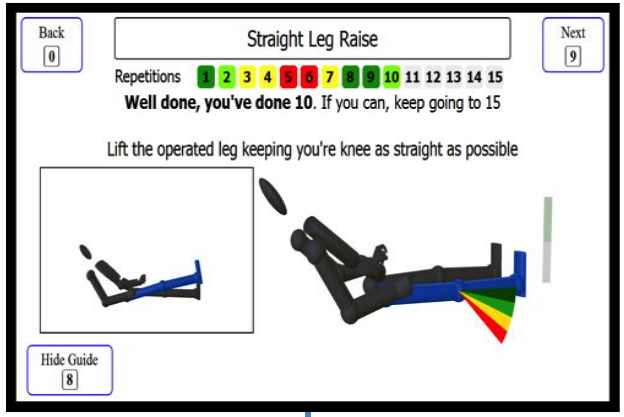
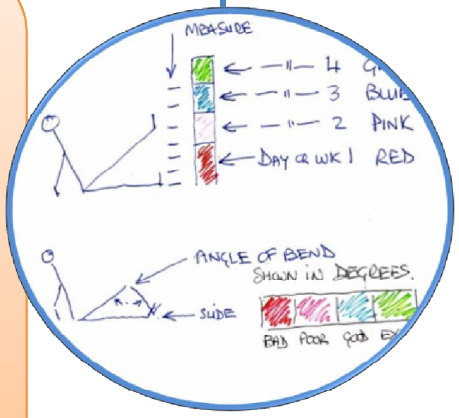


Design 2



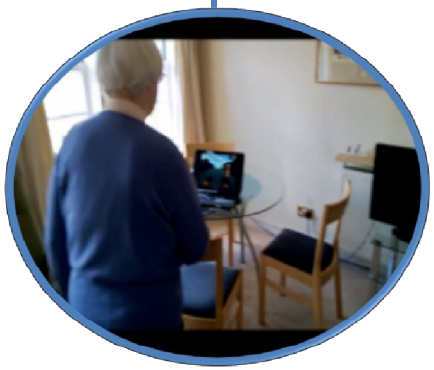
Timeline

Interviews with experts & Investigation of Technology



Design workshops

Usability studies



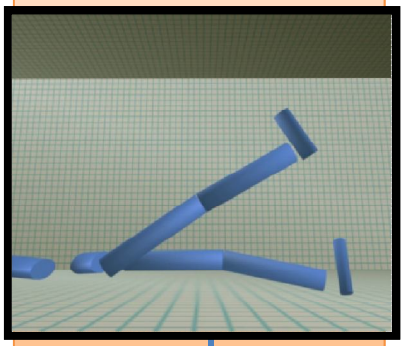
Clinical/Home studies

Design Workshop: Phase 1

	Focus	Methods
Phase 1	Investigate current situation with users	Current tools and interactions
Phase 2	1st demo of prototype system	Critiquing demo prototype
Phase 3	Suggestions for new system	Design & Redesign

Project Timeline

Basic Prototype



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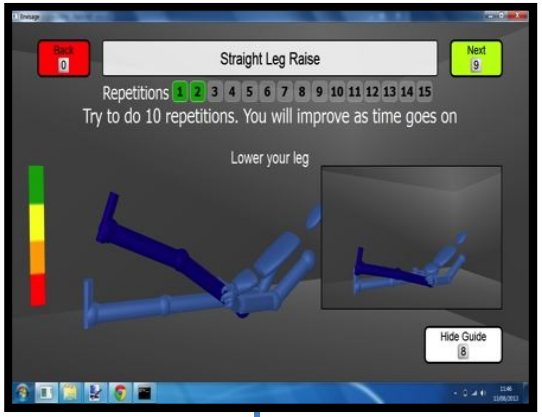
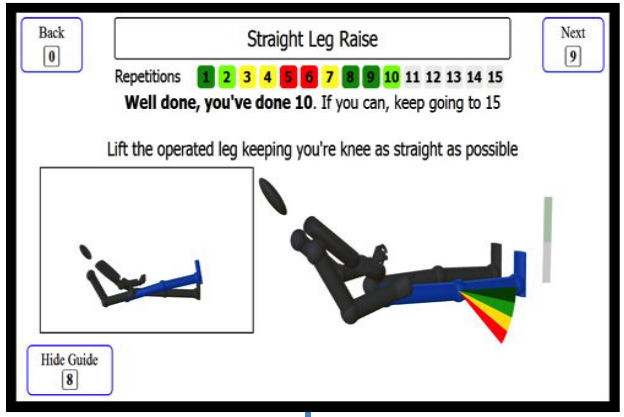
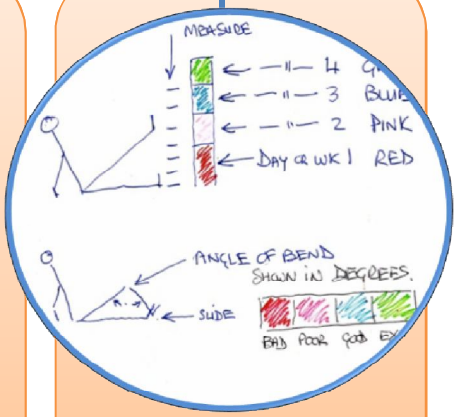


Design 2



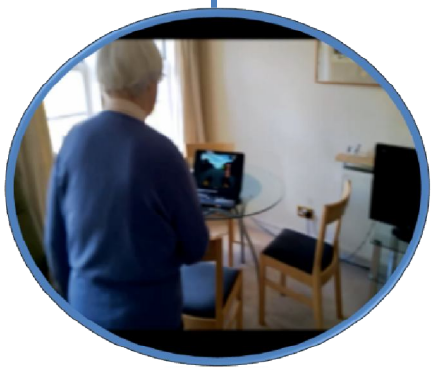
Timeline

Interviews with experts & Investigation of Technology



Design workshops

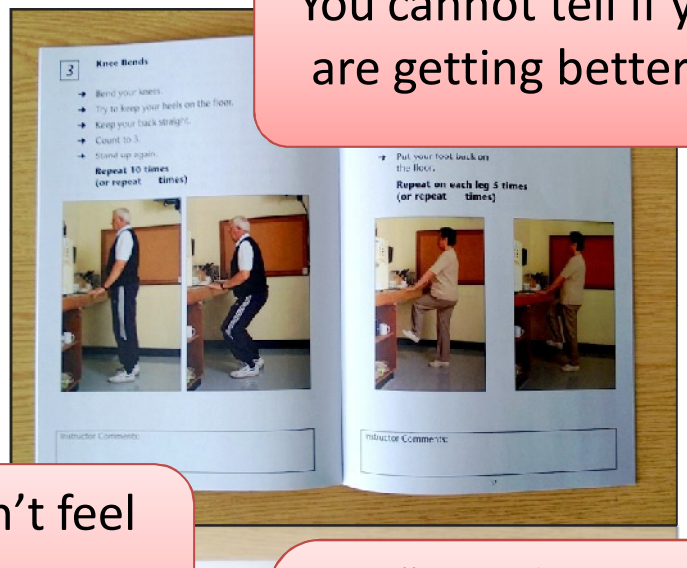
Usability studies



Clinical/Home studies

Phase 1: Investigate Current Situation

- Booklets feel passive to use
- Using the booklet is not motivating
- No feedback on performance from the video



"You cannot tell if you are getting better"

"You don't feel like you are participating"

"It is okay to use……but you do not feel motivated do you?"

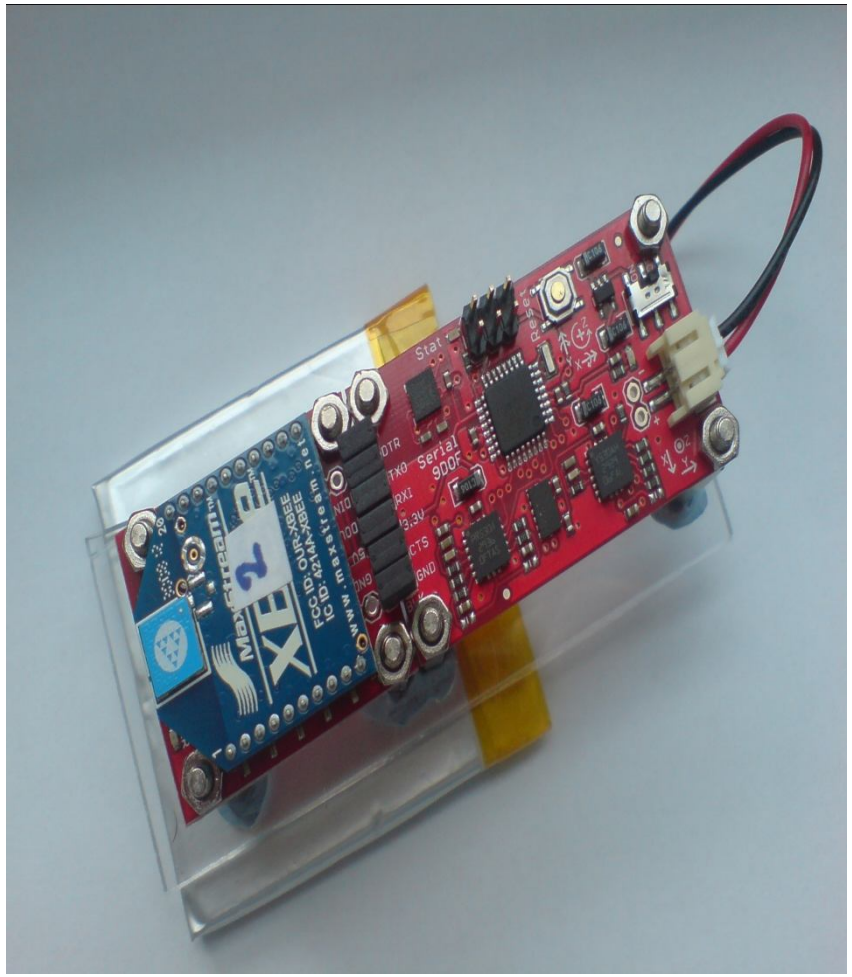
Possible Solution: motivate users through the use of well designed interactive tools that give feedback

Design Workshop: Phase 2

	Focus	Methods
Phase 1	Investigate current situation	Current tools and interactions
Phase 2	1st demo of prototype system (hardware and software)	Critiquing demo prototype
Phase 3	Suggestions for new system	Design & Redesign

Phase 2: Hardware

- *The sensor needs to be smaller than this (quite small)*
- *The user should not have to wear special clothing to use the sensors*
- *The sensors should be easy to put on and take off*
- *It should be easy to see when the sensors are on*
- *Want to be able to use the system anywhere in the home*
- *The System should be easy to interact with and learn*



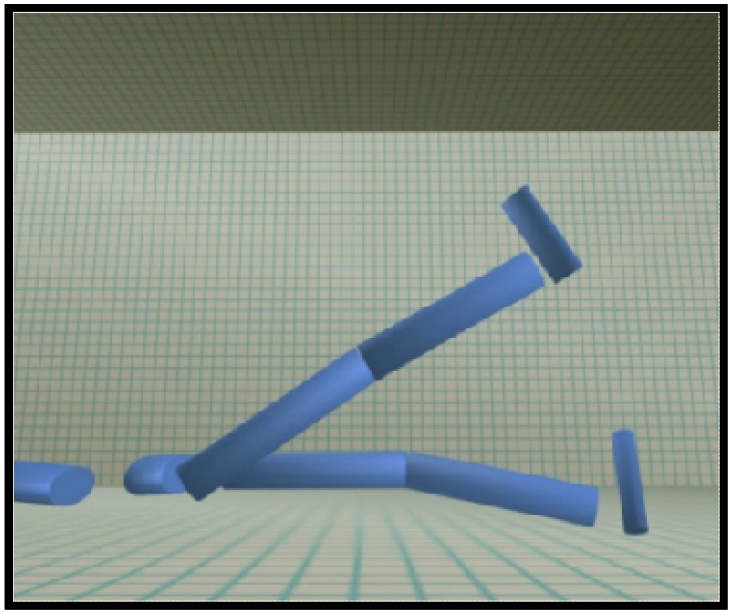
Phase 2: Visualisation

Negative

- Not sure of minimum and maximum movement
- No repetition count
- No progress shown

Positive

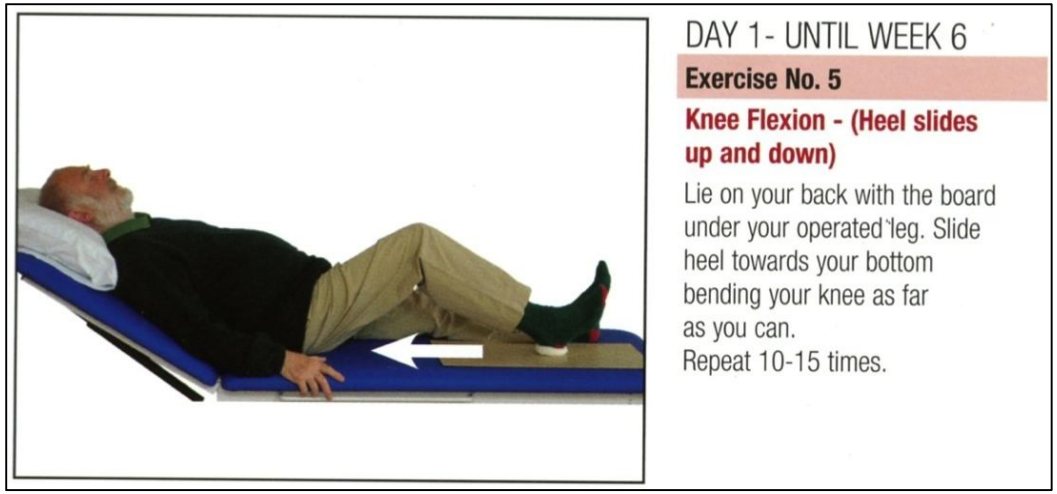
- Can see my own movement
- Can adjust my movement when I see the visual mannequin doing something different

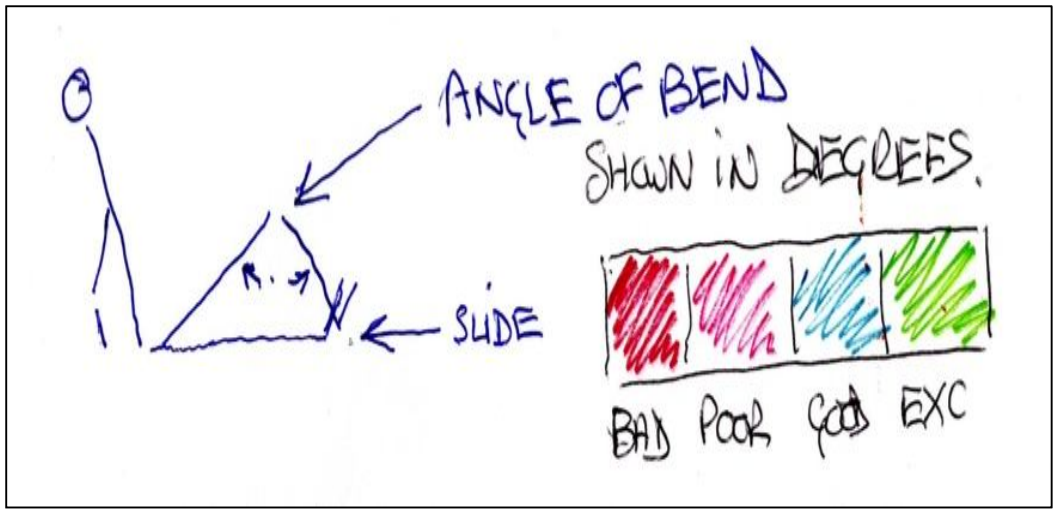


Design Workshop: Phase 3

	Focus	Methods
Preparatory Session	Planning & collecting data	Interviews, literature review, current tools
Phase 1	Investigate current situation	Current tools, technologies, interactions
Phase 2	1st demo of prototype system	Critiquing demo prototype
Phase 3	Suggestions for new system design	Design & Redesign

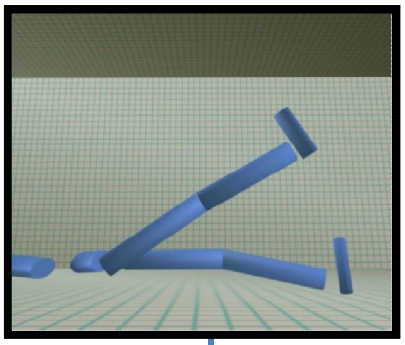
Phase 3: Suggestions for New Visualisation & Games



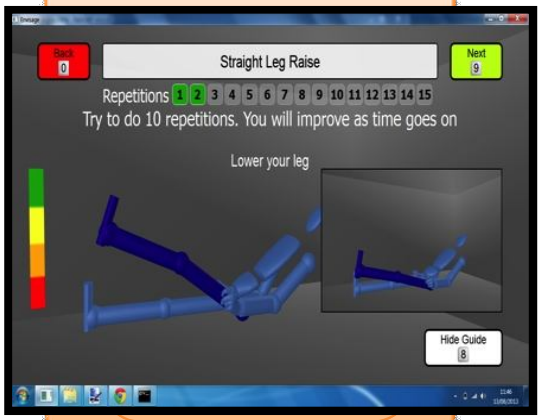


Project Timeline

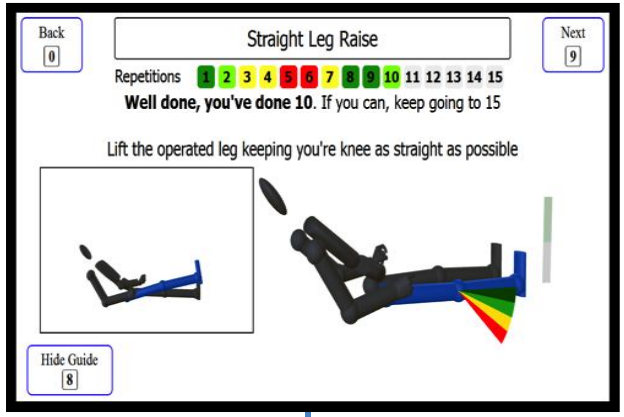
Basic Prototype



Design 1

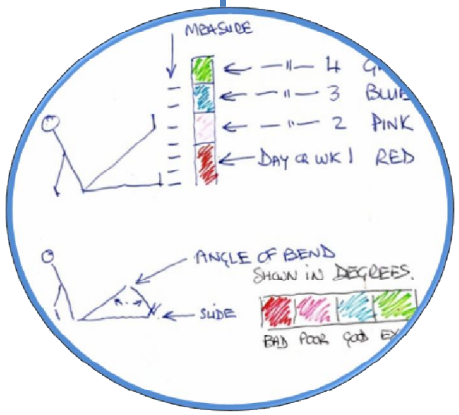


Design 2



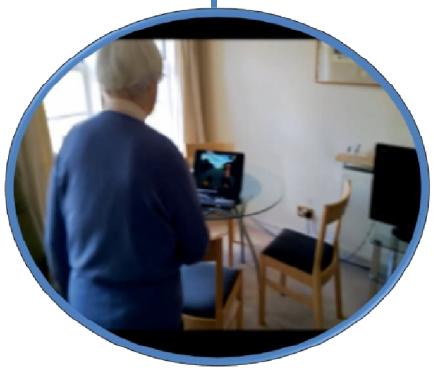
Timeline

Interviews with experts & Investigation of Technology



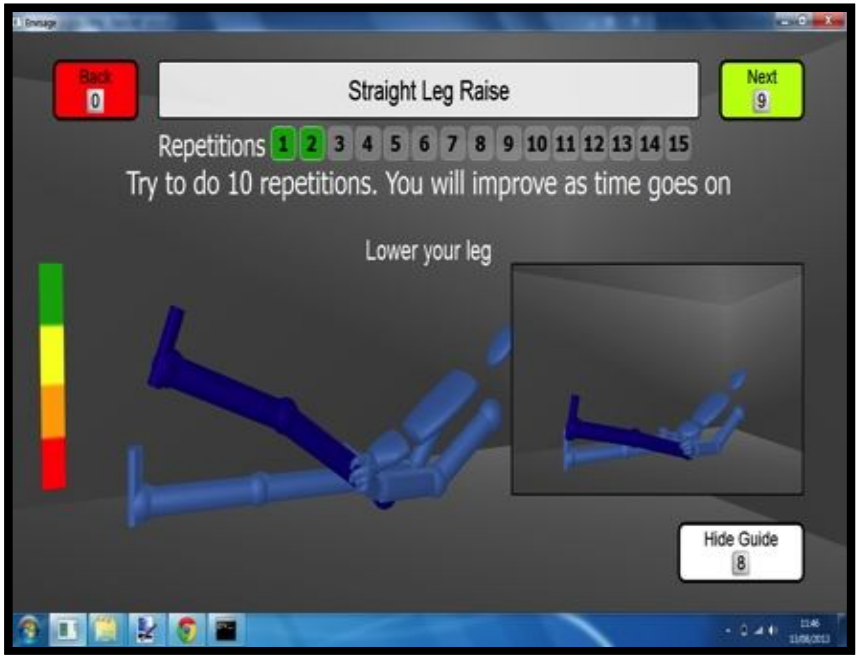
Design workshops

Usability studies

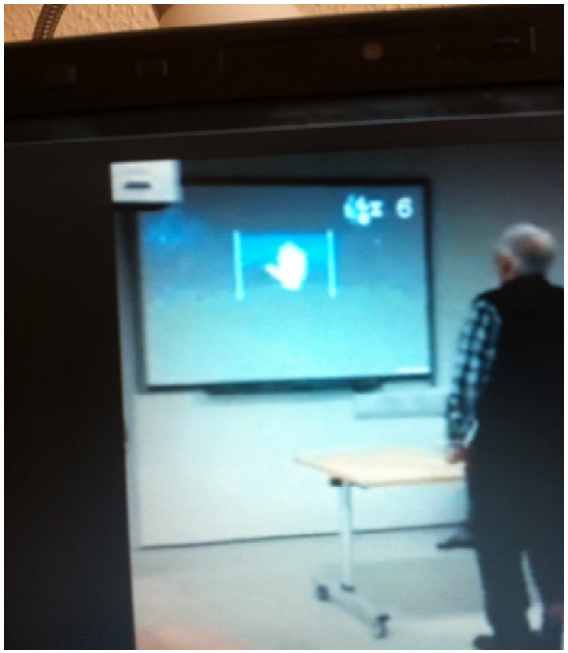


Clinical/Home studies

Software Development : Design 1

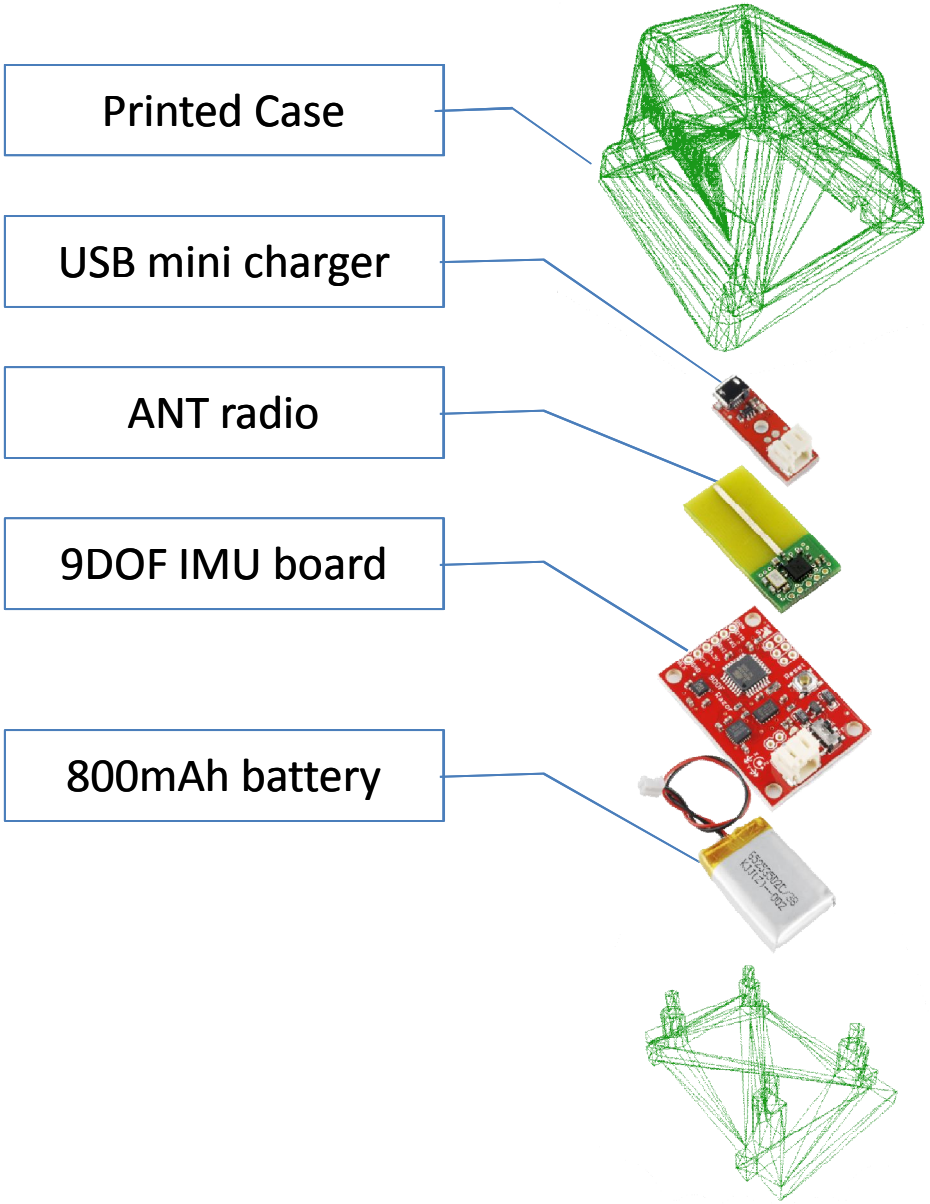


Visualisation



Game

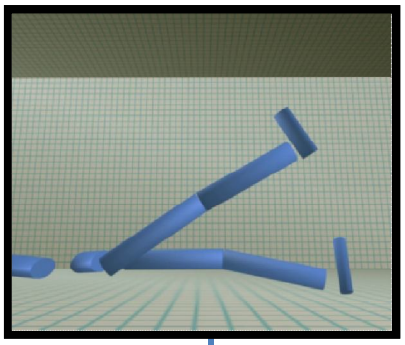
Design 1: Hardware Development



Inertial Measurement Unit (IMU) above = Accelerometer + Gyroscope + Magnetometer

Project Timeline

Basic Prototype



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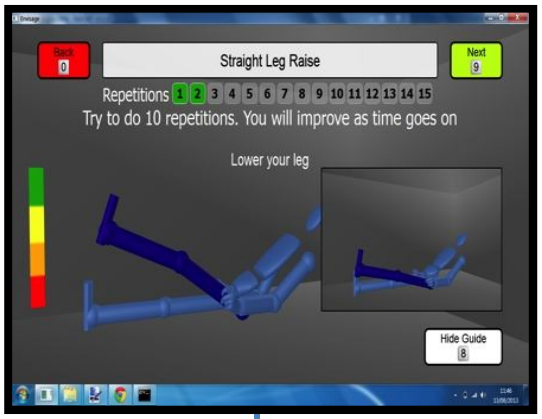

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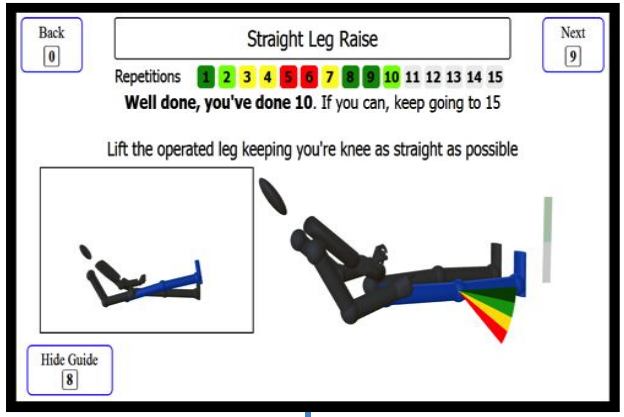

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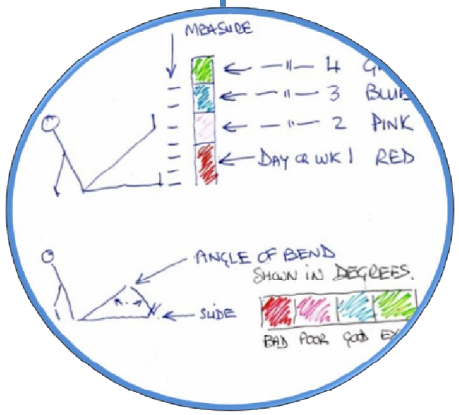
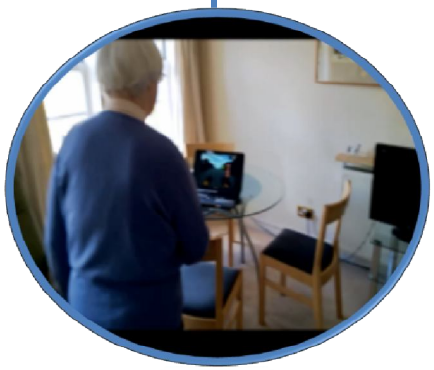


Design workshops

Usability studies

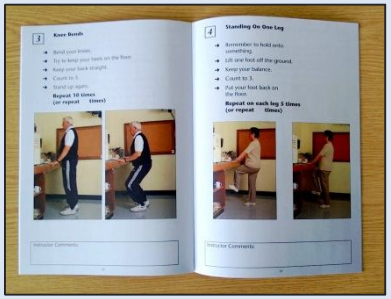


Clinical/Home studies

Usability Studies Procedure

Phase 1

Exercise with Standard care



4 exercises using the booklet

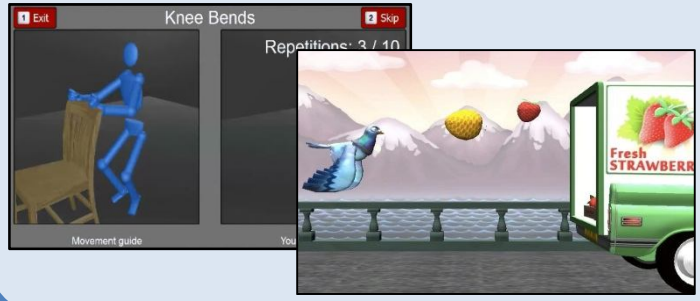
Phase 2

Putting on the sensors

Sensors were put on using on-screen instructions

Phase 3

Exercise with Visualization tool or games (+ Sensor task)



4 exercises using the visualization tool or games

- ✓ 12 Participants (6 lab and 6 home), average age: 74
- ✓ Time to complete each repetition was recorded
- ✓ We investigated the usability and acceptance of the technologies

Set up

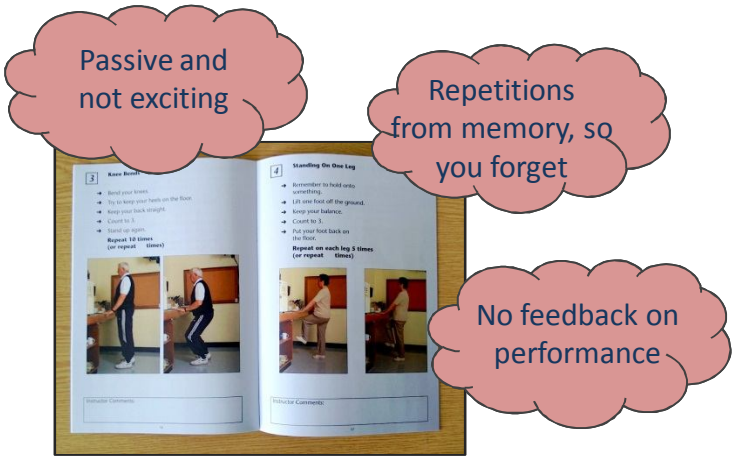
Laboratory studies

- Controlled environment
- Ample space

Home studies

- Intended environment
- Limited space

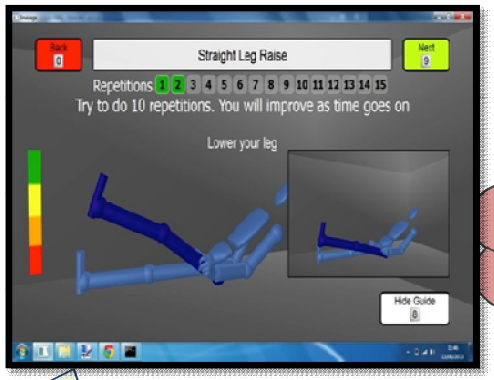
User remarks



Maximum therapeutic benefit of exercise is not assured

"It is good to see what you are doing"

Limitations of the booklet can be addressed



The screen is too dark, can it be lightened?

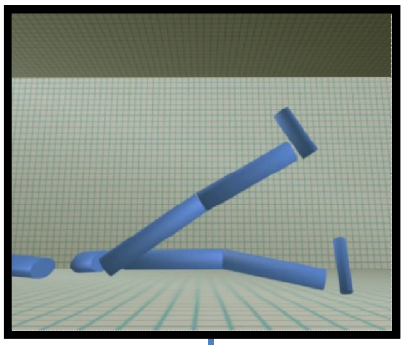
"This could give me the confidence and discipline that I need"

"I only hope I'll be able to stop playing because it is fun"

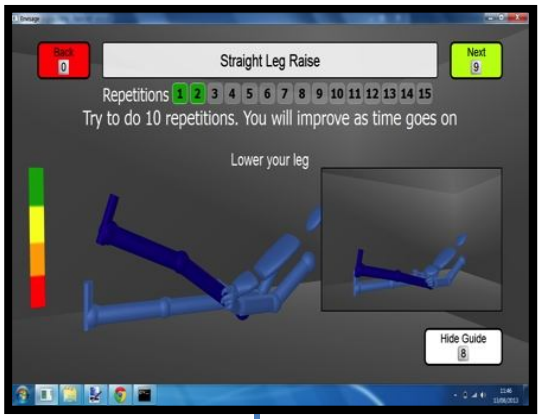
However: will these technologies encourage adherence over the full length of a rehabilitation? programme?

Project Timeline

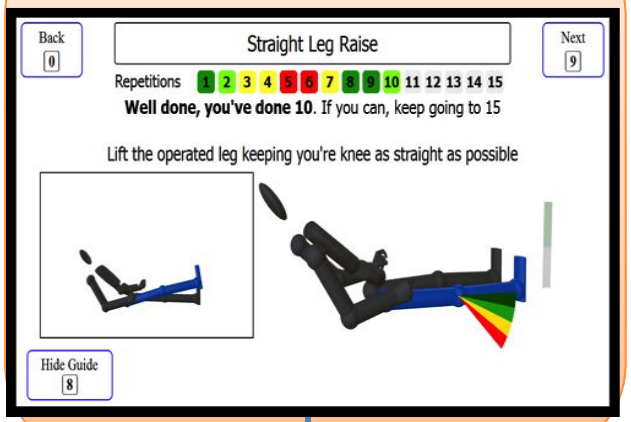
Basic Prototype



Design 1

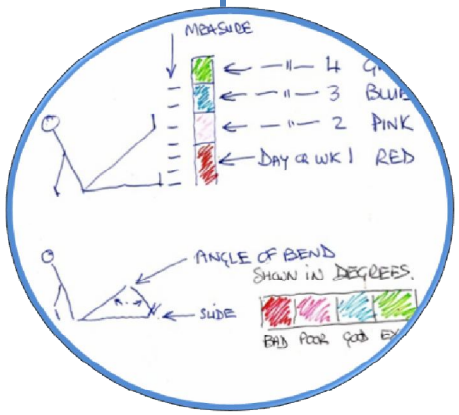


Design 2



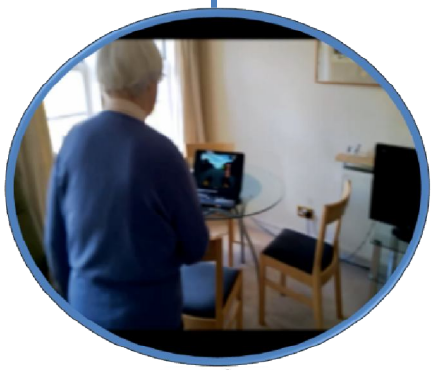
Timeline

Interviews with experts & Investigation of Technology



Design workshops

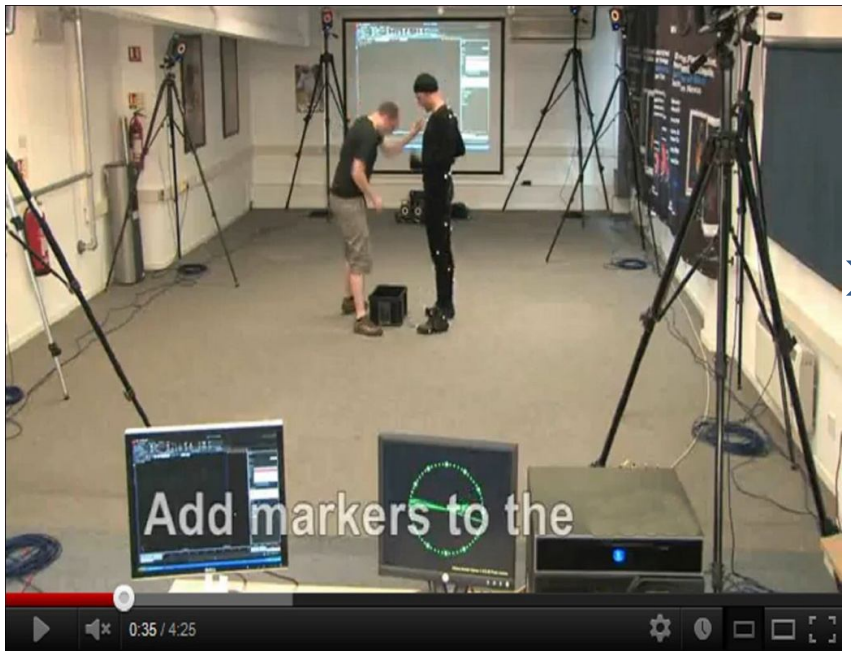
Usability studies



Clinical/Home studies

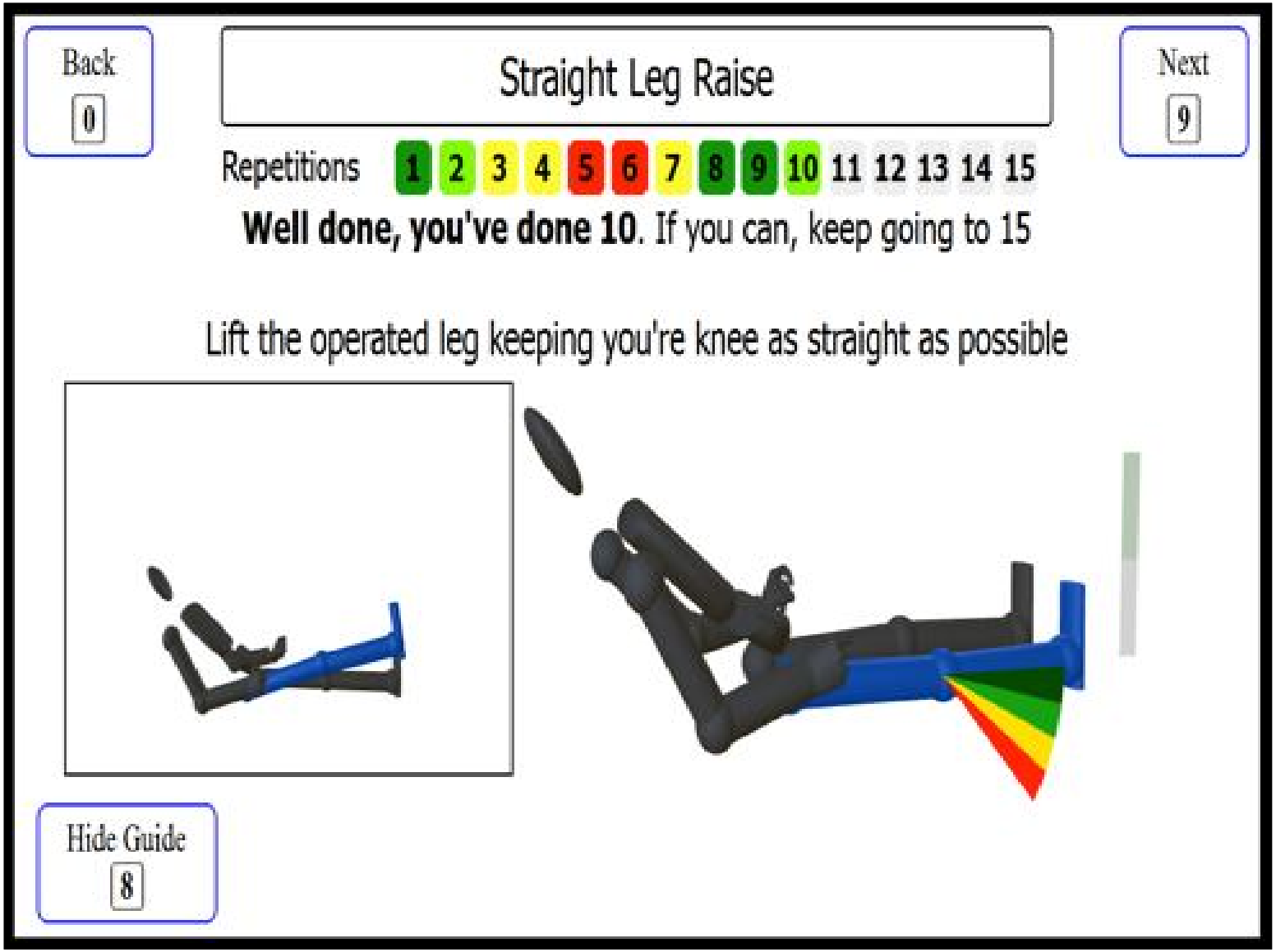
Wirless Motion Capture

Laboratory Motion Capture Technology



Home Motion Capture Technology

Final Design: Visualisation



Project Timeline

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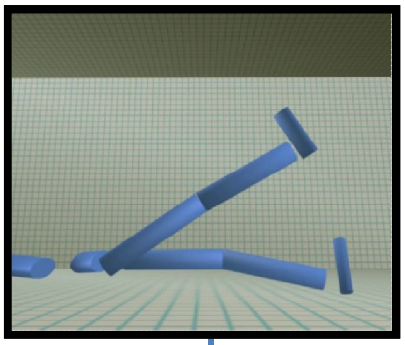
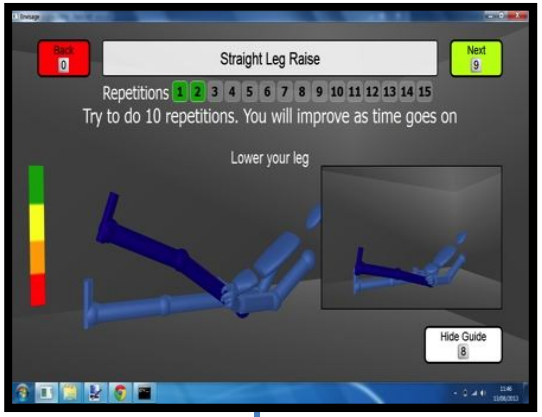
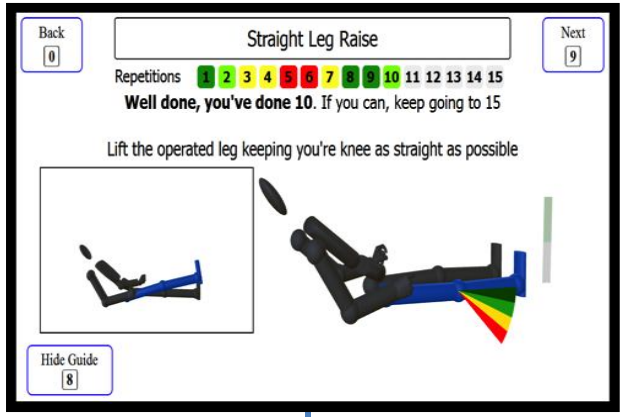


Design 1

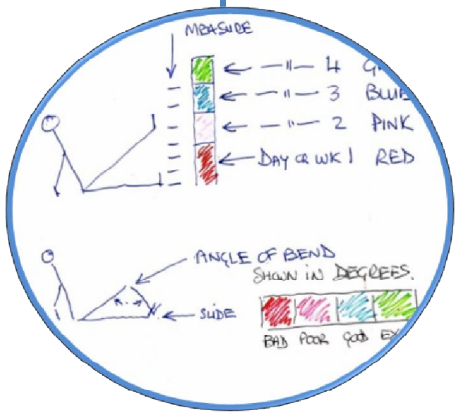


Design 2



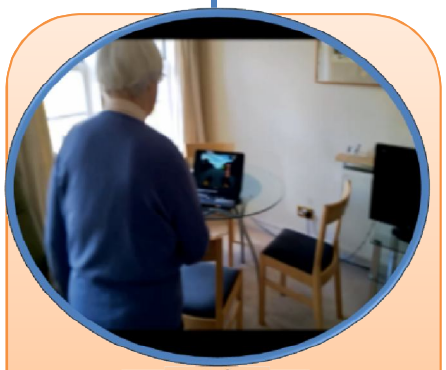
Timeline

Interviews with experts & Investigation of Technology



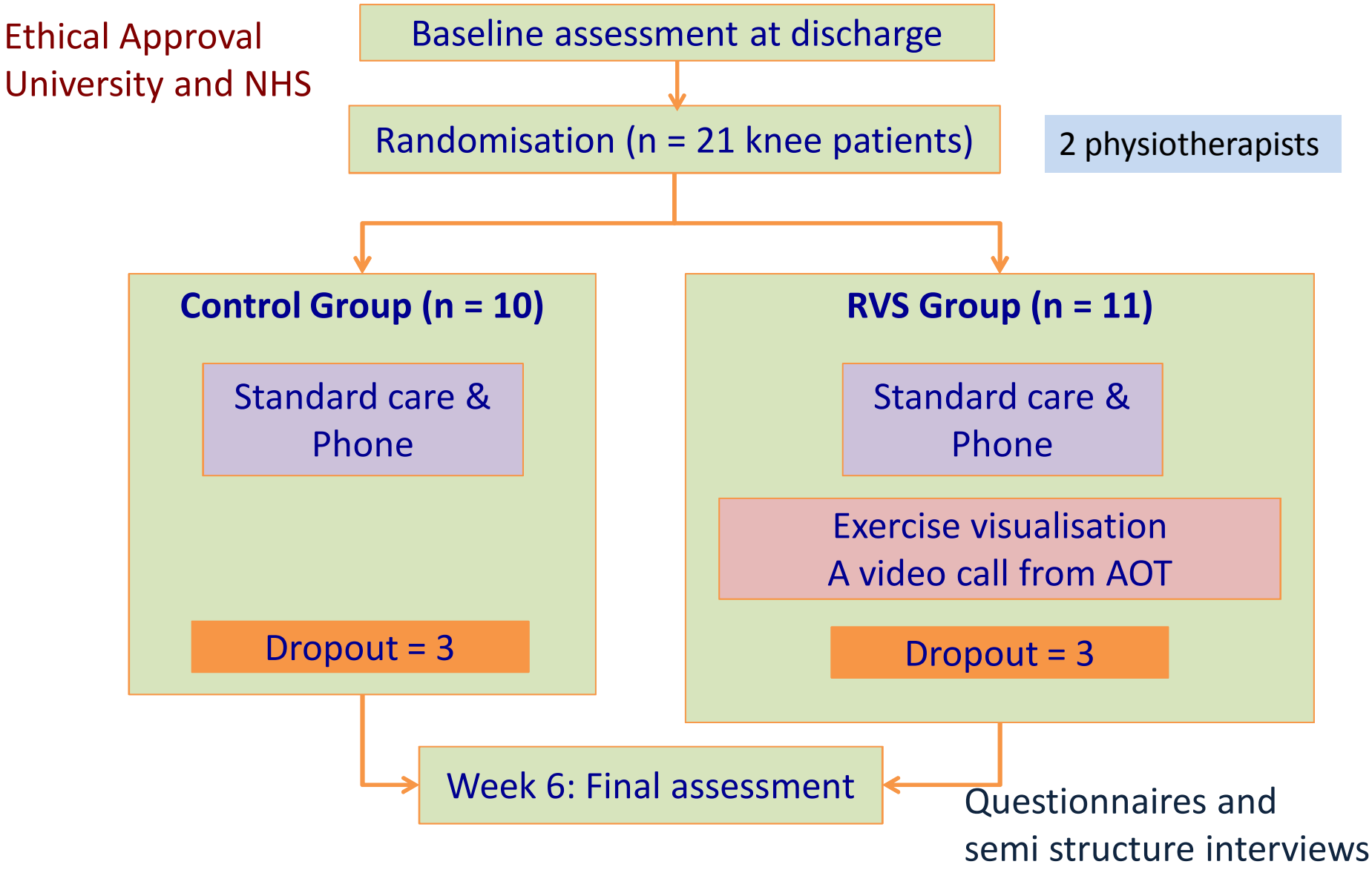
Design workshops

Usability studies



Clinical/Home studies

Study Design: Knee



Participant Demographics

Variable	Control	Experimental
Median Age (Range)	71(47 - 85)	69 (50 - 78)
Female	5	6
Male	5	5
Novice PC user	5	2
Occasional PC user	2	4
Experienced PC user	3	5

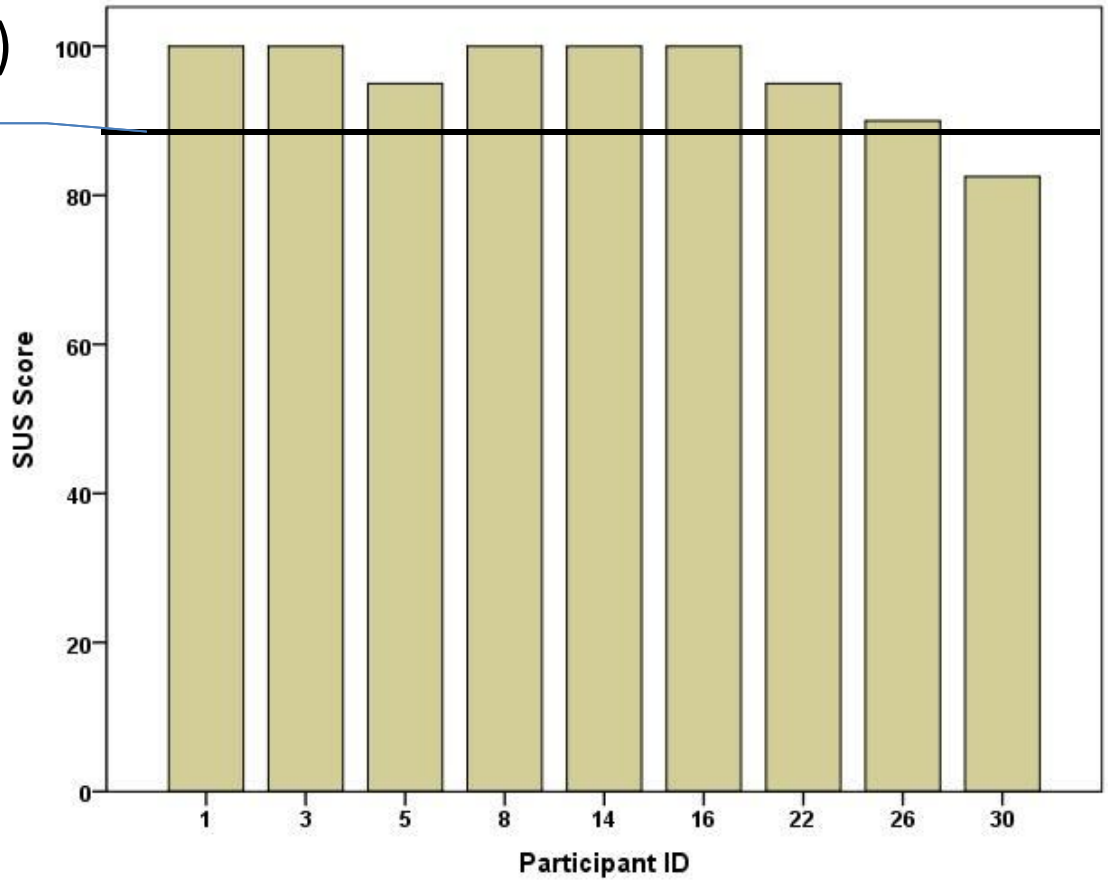
The Home Rehabilitation Session

Locations: Bedroom, living room …

Key Findings Knee - User Experience

System Usability Scale (SUS)

Best imaginable
(Bangor et al., 2009)



Enjoyment

"She was excited getting into deep green, you could hear her screaming with joy" – (spouse of P3).

Key Findings - Improved Adherence

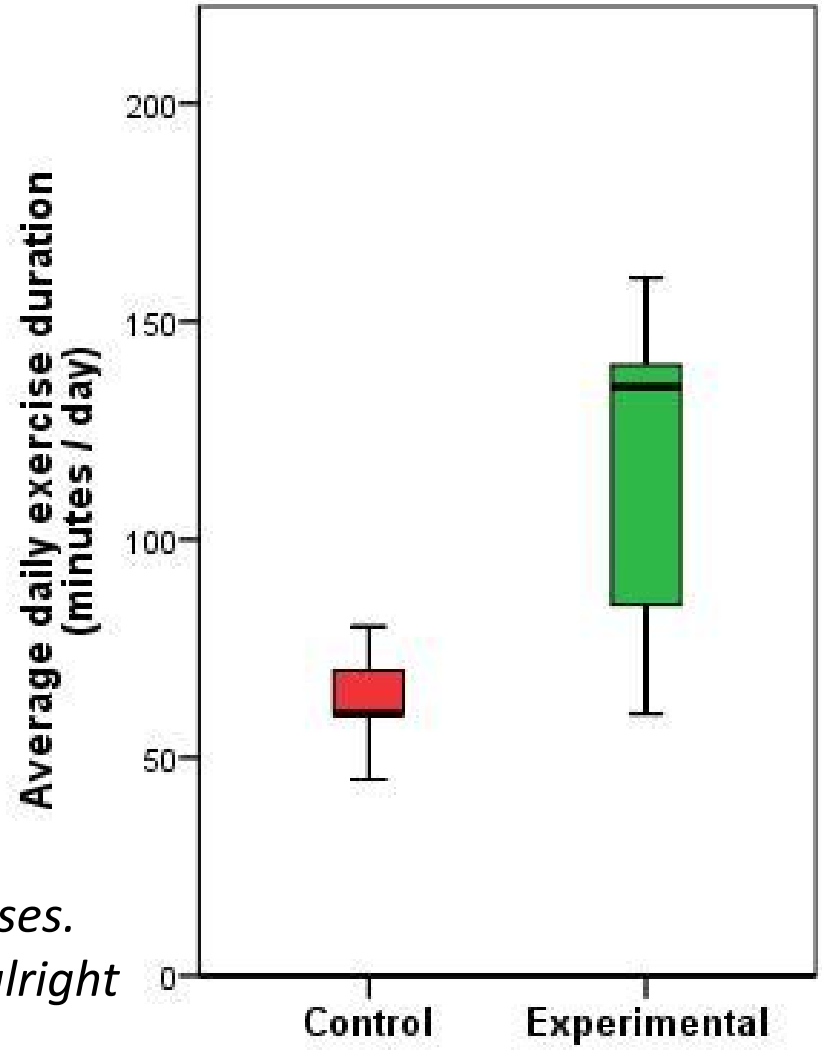
Median sessions per day

Control Group = 4

Visualisation Group = 3

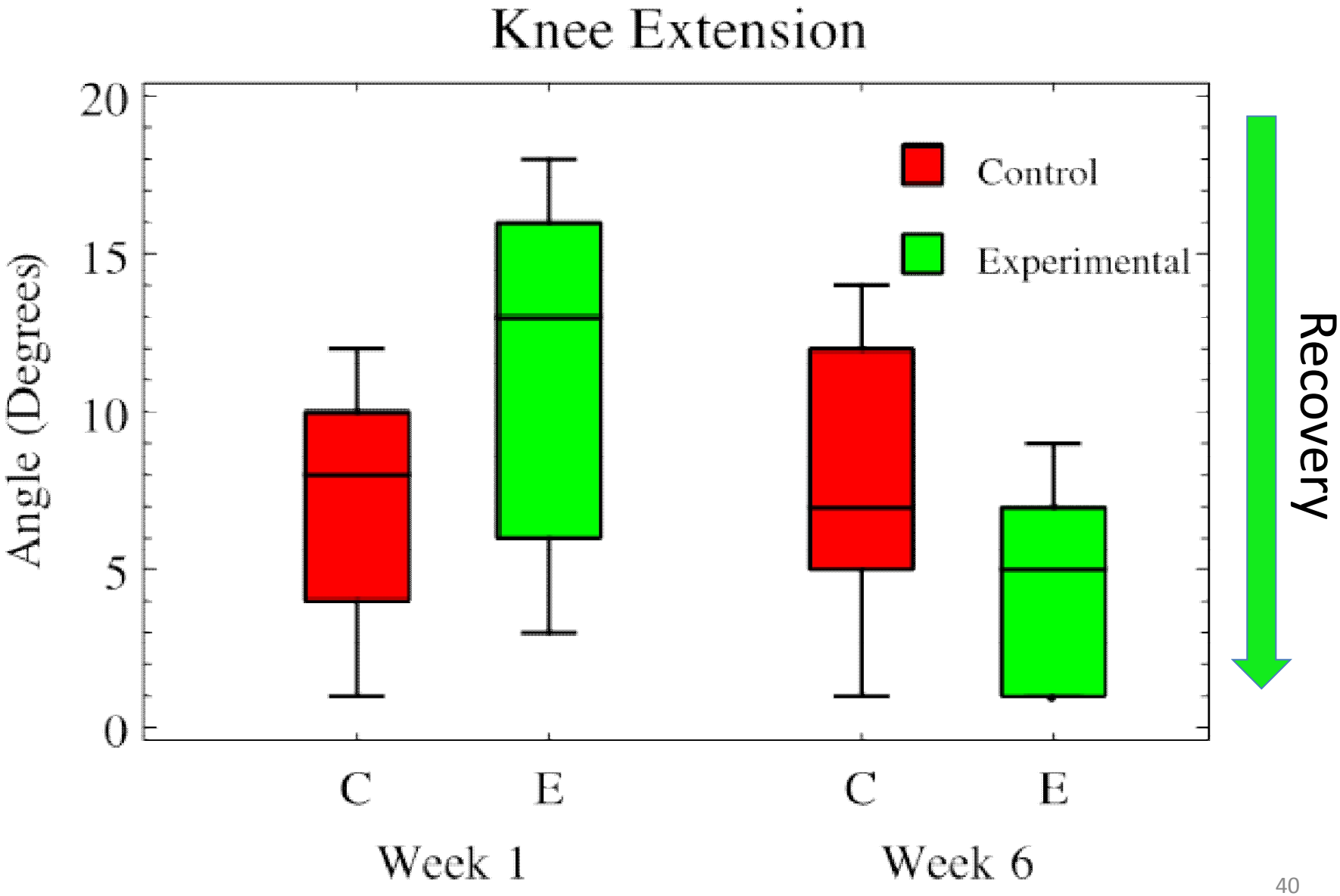
… but

- 15 repetitions
- 8 exercises per session

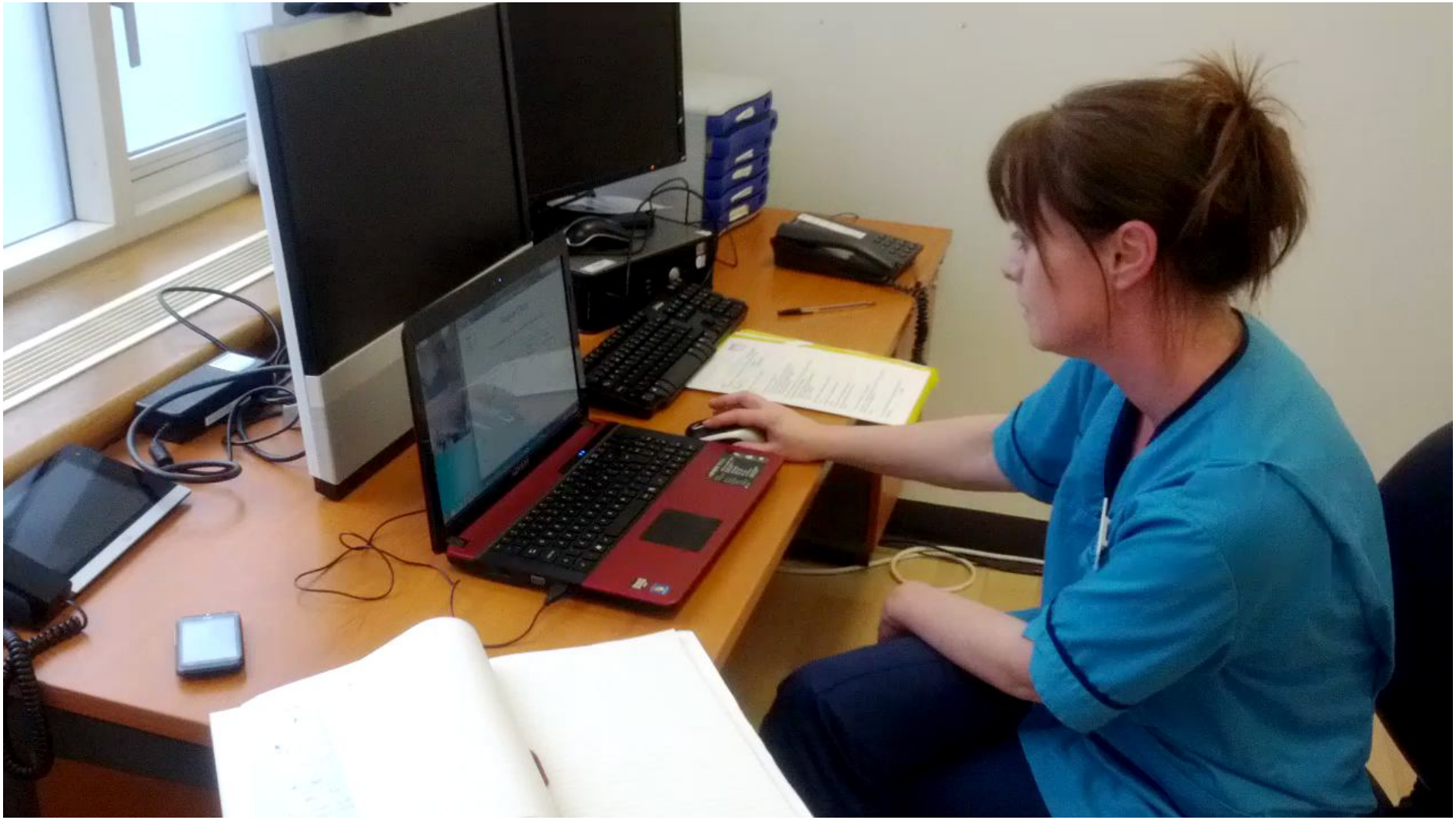


"You see this really helped me to do the exercises. If I hadn't the system, I will just say that it is alright and let it (rehabilitation) go" – (P05).

Key Findings - Rehabilitation Outcomes



Key Findings - Therapist-Patient Communication



Conclusions: Knee

Results

- The system was **acceptable and easy to use**
- The system **improved adherence** and **quality of home rehabilitation**
- The system **improved rehabilitation outcomes**
- The system **improved patient-therapist communication**

Key Elements

- Promotes correct performance in real-time
- Provides feedback on each exercise repetition
- Tracks progress in terms of quantity and quality of performance

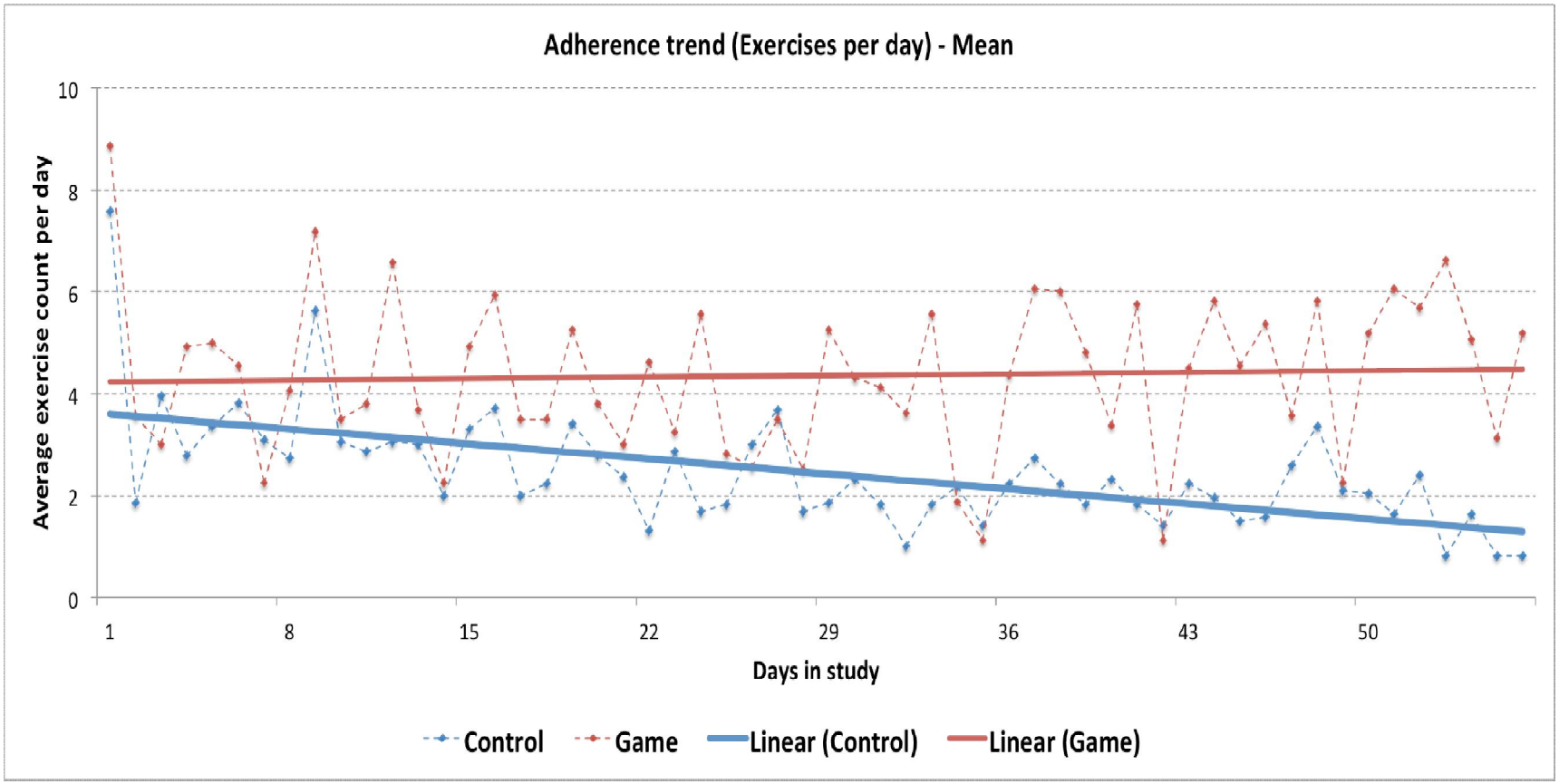
Falls Research studies – purpose, setup and hypotheses

	STUDY 1	STUDY 2	STUDY 3
STUDY DESIGN	Randomised Controlled Trial (2 groups)	Randomised Controlled Trial (2 groups)	Randomised Controlled Trial (3 groups)
STUDY GROUPS	• Recov-R group • Control group	• Recov-R group • Control group	• Recov-R group • Control group • Nintendo Wii group
DURATION	12 Weeks	8 Weeks	8 Weeks
KEY HYPOTHESES	• Recov-R system improves adherence and reduces fall risk • Recov-R system can be used independently in the home	• Recov-R system improves adherence and reduces fall risk • Recov-R system can be used independently in the community housing	• Recov-R system improves adherence and reduces fall risk • Recov-R system can be used independently in community housing in the UK and USA
PURPOSE	Pilot study of the system in seniors' homes	Larger study to confirm results of Study 1 – with focus on community housing.	• Test Recov-R system against standard care and Nintendo Wii • Test Recov-R system in

Research studies – statistics/ demographics

	STUDY 1	STUDY 2	STUDY 3
REGION (RECRUITMENT PARTNERS)	Glasgow (NHS and Glasgow Housing Association)	Glasgow (NHS and North Glasgow Homes)	Edinburgh/ West Virginia (Various associations in Lothian regions and Institute for GeriOlympics and Active Aging, WV, USA)
MALES	4	14	6
FEMALES	13	24	33
PARTICIPANTS	17	38	39
RECOV-R GAME GROUP	8	16	20
CONTROL GROUP	9	22	19
AGE RANGE (MEDIAN AGE)	65 – 84 years (75.5 years)	65 – 99 years (76 years)	55 – 94 years (77.5 years)

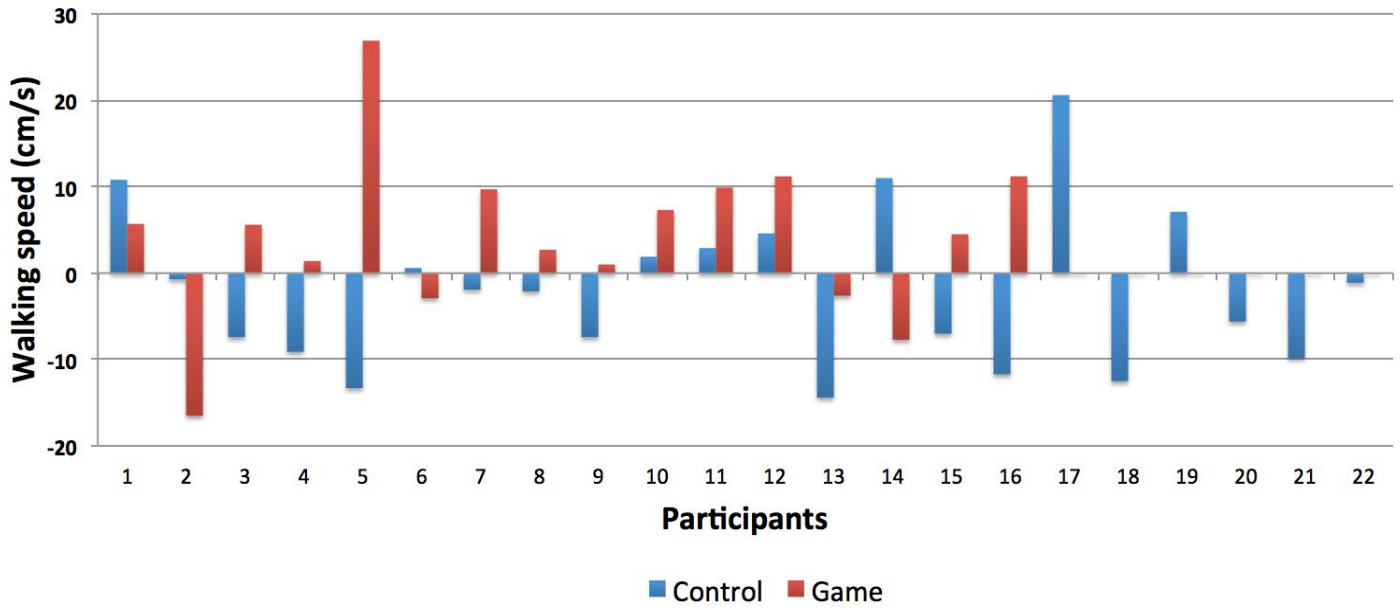
Adherence – number of exercises done



The system encouraged the older adults to exercise regularly, compared to the standard care group, where there was a steady decline in adherence to exercise

The findings on adherence are statistically significant using a comparative T-Test ($p = 5 e\text{-}11$) with a significance value of $p = 0.05$

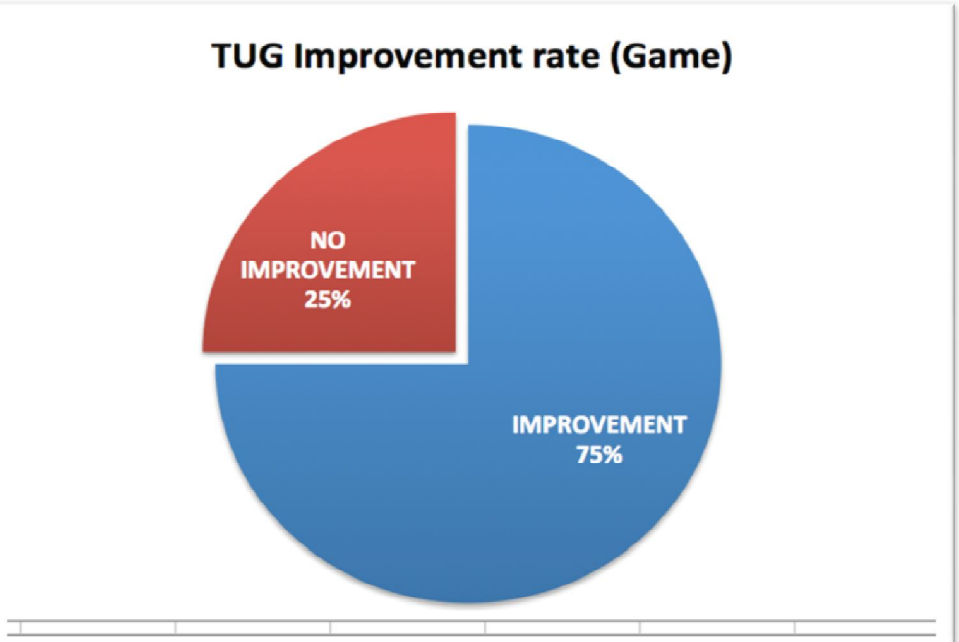
Improvement in mobility (clinical outcome)

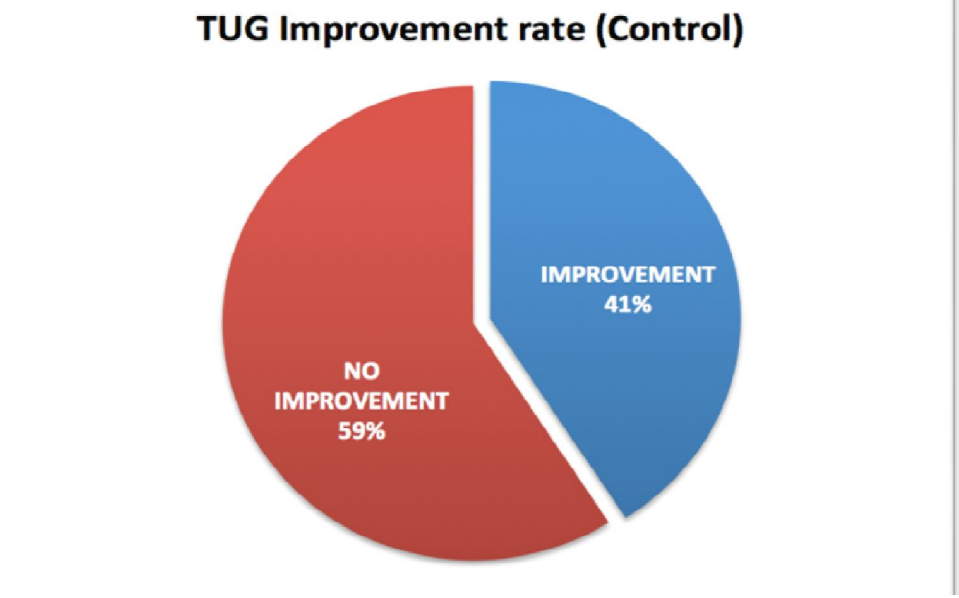


12/ 16, participants in the Game group (75%) improved in average walking speed compared to a corresponding 8/22 participants in the Control group (36%). This suggests that the system encouraged better quality of movement during exercise – leading to a reduced risk of falling

The findings on walking speed are statistically significant using a T-Test (p = 0.047) with a significance value of p = 0.05

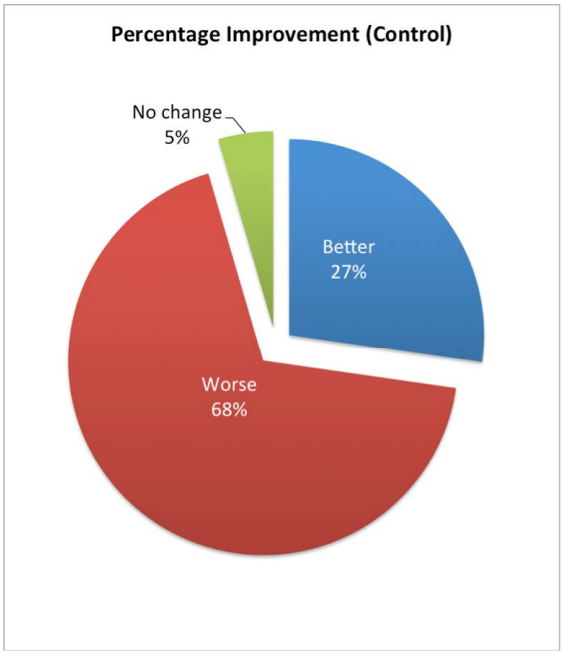
Improvement in balance (timed up and go test)

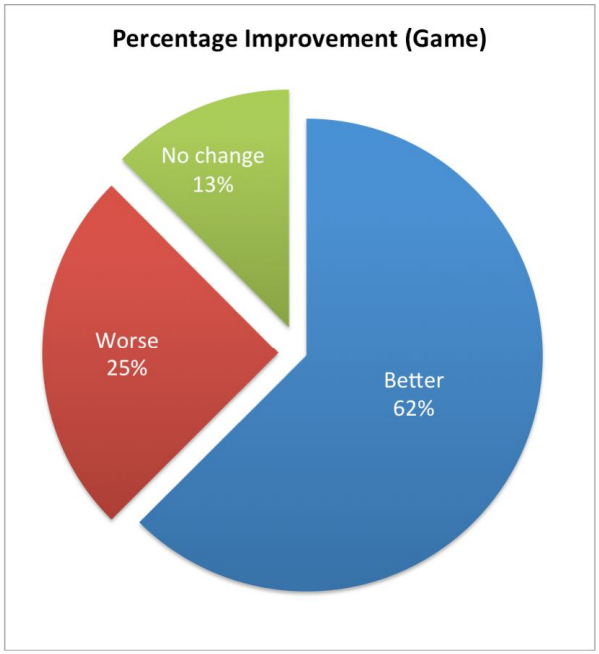




There were *significantly more* seniors who improved in balance, after using the Recov-R system **(75%)**, versus those in the control group who used standard care **(41%)**. This demonstrates the system's capability to improve physical function in terms of balance (necessary for reducing risk of falling)

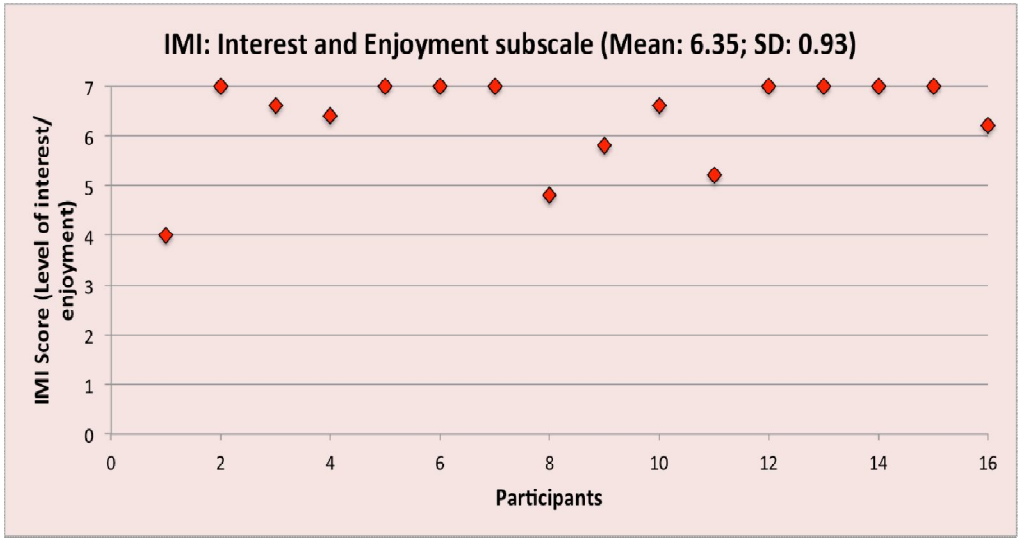
Improvement in fall concern (Falls efficacy scale - FES)

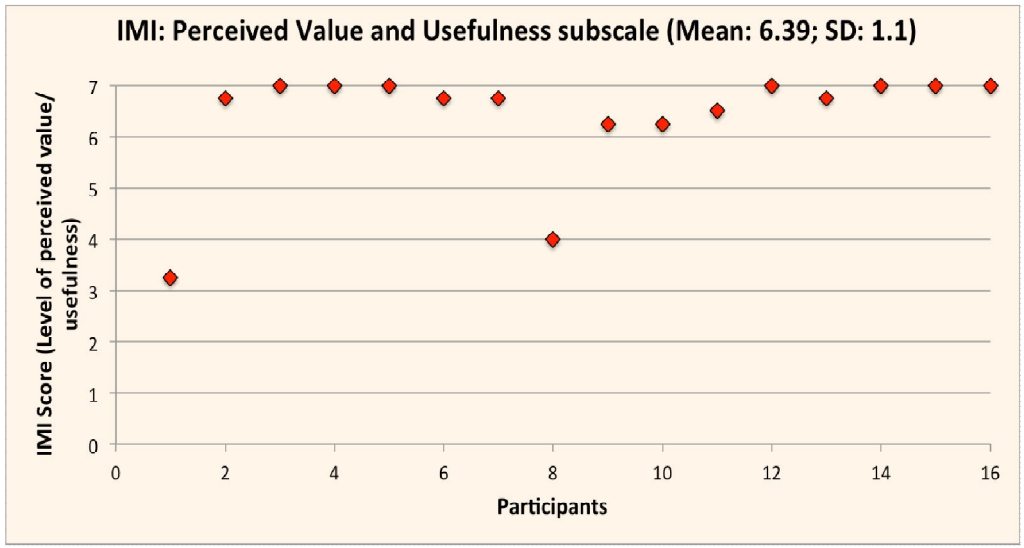




There were significantly more seniors who were less concerned about falling, after using the Recov-R system (62%), versus those who used standard care (27%). This demonstrates the system's capability to improve confidence and reduce fear of falling (and consequently reduce risk of falling)

IMI Scale – Interest & Enjoyment





The scale goes from 1. Not at all interesting/Enjoyable to 7 Very interesting/Enjoyable.

The high values on the 'Enjoyment' scale indicate that the games were very enjoyable to the seniors, and that they were primary motivator for exercise

The high values on the 'Value/ Usefulness' scale indicate that the seniors attach high value and usefulness to the Recov-R system for the purpose of physical rehabilitation

Thank You For Your Attention
Any Questions

Contact Details:

l.baillie@hw.ac.uk (http://www.ittgroup.org)

Publications associated with research talk:

Uzor, S. & **L. Baillie**. Investigating the Long-Term Use of Exergames in the Home with Elderly Fallers. In proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI), 2014.

Ayoade, M. and **Baillie, L**. (2014). A Novel Knee Rehabilitation System for the Home. In proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI), 2014.