

**The Use of Interactive Game Technology to
Improve the Physical Health of the Elderly:
A Serious Game Approach to Reduce the
Risk of Falling in Older People**

A thesis submitted by **Jaime A. Garcia Marin**
in fulfilment of the requirements for the award of the degree
Doctor of Philosophy
in Software Engineering and Information Systems

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Certificate of Original Authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text. I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abstract

The elderly population is growing dramatically both in Australia and globally. With age, the human body undergoes a series of changes that can lead to decline in mental and physical health. Decline in motor functions increases the risk of developing health problems such as postural instability, balance disorders or simply having a fall. Falling is the main cause of disability and fatality among the elderly. Statistics show that one in three older adults might experience a fall every year. This could be prevented with regular exercise. Exercises with a walking component have proven to reduce falls by 40%. However, compliance with physical activity is often poor due to the mode of delivery, which is often unattractive. One approach that might help alleviate this is the use of commercial video games to engage the elderly in physical exercise. However, this practice may have undesirable results as such games are not designed to provide therapeutic support for the elderly but instead to entertain a much younger audience.

This thesis aims to solve the above problem through the use of interactive game technology by testing that optimal results for the health of the elderly come from the combination of three elements:

- the integration of a formal method to assess progress towards and the achievement of the desired health outcomes,
- inclusion of meaningful tasks aligned with the specific health objectives
- an appropriate game design through the use of user-centred design methodologies.

Firstly, literature in the area of video games with health purposes for the elderly is reviewed to develop a clear understanding of the health issues and the research opportunities in the area. Secondly, a series of game prototypes is built and tested to investigate whether off-the-shelf game technology can be used to reliably perform a clinical test for fall risk assessment. Then a game is developed that aims to reduce the risk of falling by training a set of specific cognitive and physical functions that have been shown to be associated with falling. This prototype, known as the *StepKinnection* game, integrates the concept of an appropriate game design for the elderly, inclusion of meaningful tasks and the collection of stepping performance data. Thirdly, a series

of studies on independent-living people aged 65 years and over are conducted. These studies confirmed the ability to reliably perform a clinical test using off-the-shelf game technology, the acceptance and ease of use of the *StepKinnection* game, and the potential of *StepKinnection* to reduce the risk of falling in the elderly.

Finally, an analytical framework is developed for designing interactive games with health purposes for the elderly. This framework aims to assist the development of games aligned to particular health outcomes. This framework emphasises the importance of aligning the game goals to the expected health outcomes as well as the continuous assessment of progress and effectiveness.

Publications Supporting this Thesis

The following is a list of accepted refereed publications resulting from this thesis.

Journals

1. **Garcia, Jaime A**, Karla Felix Navarro, Daniel Schoene, Stuart T Smith, and Yusuf Pisan (2012), “Exergames for the elderly: Towards an embedded kinect-based clinical test of falls risk.” *Stud Health Technol Inform*, 178, 51-7.

Conferences

1. **Garcia, Jaime A** and Karla Felix Navarro (2015), “Step Kinnection: A Fall Prevention Game Mindfully Designed for the Elderly.” In *Australia’s premier digital health, health informatics and e-health conference and expo, HIC2015*, HISA.
2. **Garcia, Jaime A**, Yusuf Pisan, Chek Tien Tan, and Karla Felix Navarro (2014), “Assessing the kinect’s capabilities to perform a time-based clinical test for fall risk assessment in older people.” In *Entertainment Computing - ICEC 2014*, 100-107, Springer.
3. **Garcia, Jaime A**, Yusuf Pisan, Chek Tien Tan, and Karla Felix Navarro (2014), “Step Kinnection: a hybrid clinical test for fall risk assessment in older adults.” In *CHI’14 Extended Abstracts on Human Factors in Computing Systems*, 471-474, ACM.
4. **Garcia, Jaime A** and Karla Felix Navarro (2014) “The Mobile RehAppTM: an AR-based mobile game for ankle sprain rehabilitation.” In *3rd International Conference on Serious Games and Applications for Health, SeGAH 2014*, IEEE.
5. Pisan, Yusuf, **Jaime A Garcia**, and Karla Felix Navarro (2013), “Improving lives: using microsoft kinect to predict the loss of balance for elderly users under cognitive load.” In *Proceedings of The 9th Australasian Conference on Interactive Entertainment: Matters of Life and Death*, 29, ACM.

6. Felix Navarro, Karla, Elaine Lawrence, **Jaime A Garcia**, and Christian Sax (2011), “A dynamic and customisable layered serious game design framework for improving the physical and mental health of the aged and the infirm.” In *The Third International Conference on eHealth, Telemedicine and Social Medicine (eTELEMED 2011)*, 140-145.
7. Lawrence, Elaine, Karla Felix Navarro, **Jaime A Garcia**, and Christian Sax (2011), “Towards building health systems.” In *ICONS 2011, The Sixth International Conference on Systems*, 109-114.
8. **Garcia, Jaime A.**, Karla Felix Navarro, and Elaine Lawrence (2011), “Serious games to improve the physical health of the elderly: A categorization scheme.” In *CENTRIC 2011, The Fourth International Conference on Advances in Human-oriented and Personalized Mechanisms, Technologies, and Services*, 64-71.
9. **Garcia, Jaime A** , Elaine Lawrence, Karla Felix Navarro, and Christian Sax (2011), “Heuristic evaluation for interactive games within elderly users.” In *eTELEMED 2011, The Third International Conference on eHealth, Telemedicine, and Social Medicine*, 130-133.

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