A NEW APPROACH FOR PERSONALIZED FALL RISK PREDICTION & PREVENTION: TAILORED EXERCISES, UNOBTRUSIVE SENSING & ADVANCED REASONING

Wieching, Rainer[1]; Kaartinen, Nico[2]; DeRosario, Helios[3]; Baldus, Heribert[4]; Eichberg, Sabine[5]; Drobics, Mario[6]; Delbaere, Kim[7]

[1]University of Siegen, Germany; [2]Kaasa Solution GmbH, Germany; [3]Instituto Biomechanica de Valencia, Spain; [4]Philips Research Europe, Netherlands; [5]German Sports University, Germany; [6]Austrian Institute of Technology, Austria; [7]Neuroscience Research Australia, Australia.

In our ageing society, falls and their consequences cause tremendous problems as related to fractures, quality of life and health care costs. Due to the ongoing changes in the age structure of the population, this problem with all its consequences will further increase in the near future and innovative solutions to avoid falls in community dwelling older adults are urgently needed. The aim of iStoppFalls is to develop and implement ICT-based technologies which can be easily integrated in daily life practices of older people living at home, and which allow for continuous exercise training, reliable fall risk assessment, and appropriate feedback mechanisms, based on discreet measuring technologies and adaptive assistance functions. The Senior Mobility Monitor (SMM) as a component of the iStoppFalls system will unobtrusively and continuously monitor mobility in daily life. It will evaluate quantitative information on frequency, duration and type of mobility activities and qualitative information on balance function and muscle power. On the other hand, our Kinect based fall preventive exercise training game (Exergame) will facilitate real preventive exercise training at home (3 times a week), where data is acquired by unobtrusive sensing together with biomechanical modeling and optional heart rate data assessment. Our Knowledge Based System for Fall Prediction & Prevention correlates these two types of mobility analysis information (SMM & Exergame), and in turn provides sufficient data to perform a trend analysis of these entities, thus evidencing valid fall prediction & sustainable fall prevention in terms of tailored home based exercises for community-dwelling older adults. Our iTV component and the whole iStoppFalls system will be based on user-centered design and living-lab approaches, and thus provides advanced HCI adjusted to the capabilities of our elderly users (usability & accessibility). ***Keywords:*** Fall Risk Prediction; Balance Function; Technology; Fractures; Quality of Life.

Introduction to the iSTOPPFALLS project

Wieching, Rainer; Wulf, Volker

University Siegen, Germany.

In our ageing society, falls and their consequences cause tremendous problems as related to fractures, quality of life and health care costs. Due to the ongoing changes in the age structure of the population, this problem with all its consequences will further increase in the near future and innovative and cost effective solutions to avoid falls in community-dwelling older adults are urgently needed. Hereby active prevention plays an important role, especially in terms of fall-specific exercises and training programs. Modern information and communication technologies (ICT) in the field of home-based sensor technology, telemedicine and video games can support appropriate activities excellently as they are motivating and increasingly used by older people living at home. The aim of iStoppFalls is to develop and implement ICT-based technologies which can be easily integrated in daily life practices

of older people living at home, and which allow for continuous exercise training, reliable fall risk assessment, and appropriate feedback mechanisms, based on discreet measuring technologies and adaptive assistance functions. The Senior Mobility Monitor (SMM) as a component of the iStoppFalls system will unobtrusively and continuously monitor mobility in daily life. It will evaluate quantitative information on frequency, duration and type of mobility activities and qualitative information on balance function and muscle power. On the other hand, our Kinect based fall preventive exercise training game (Exergame) will facilitate real preventive exercise training at home (3 times a week), where data is acquired by unobtrusive sensing together with biomechanical modelling and optional heart rate data assessment. Our Knowledge Based System for Fall Prediction & Prevention correlates these two types of mobility analysis information (SMM & Exergame), and in turn provides sufficient data to perform a trend analysis of these entities, thus evidencing valid fall prediction & sustainable fall prevention in terms of tailored home based exercises for community-dwelling older adults. Our iTV component and the whole iStoppFalls system will be based on user-centered design and living-lab approaches, and thus provides advanced HCI adjusted to the capabilities of our elderly users (usability & accessibility). Our first iStoppFalls prototype will be evaluated and further enhanced based on the results of an initial pilot trial with 20 participants in Germany and Australia. The final iStoppFalls demonstrator will be evidenced by a randomized clinical trial with 360 participants which will be implemented in Germany (90), Finland (45), Spain (45), and Australia (180).

Home-based exergaming: An effective fall preventive measure for the elderly

Smith, Stuart T; Delbaere, Kim; Lord, Stephen R

Neuroscience Research Australia, Australia.

With the expected increase in the number of people living to an older age, fall-related injury threatens to place significant demands on our public health care system. Fall-related injuries are the leading cause of injury-related hospitalisation in old age and with at least one third of community dwelling adults aged 65 and over fall once or more per year, the health burden within the community associated with falls is enormous. Over the past few decades, there has been a wealth of published scientific evidence for the physical, cognitive and social health-related benefits of increased exercise, especially in older adults. In particular, improvements in strength, balance, coordination and aerobic capacity leading to reduced levels of disability and better mobility function, as well as reduced fall risk in older populations, have been shown following exercise interventions. Despite the clear evidence base demonstrating the health-related benefits of PA, uptake and adherence to PA programs is often disappointing. Barriers to adherence may include lack of interest in the program, low outcomes expectation, the weather or even a fear of falling during exercise. Yardley and colleagues [1] report that home-based exercise has the widest appeal to older adults, and is also most attractive to those more socially deprived people who have the greatest need for undertaking falls prevention measures. One method by which compliance with exercise programs could be improved involves the use of fun and engaging videogames. Interactive videogames that combine player movement, engaging recreation, immediate performance feedback and social connectivity via competition, have been shown to promote motivation for, and increase adherence to, physical exercise amongst children and young adults. In older adults, videogames have also been shown to improve cognitive abilities, to be a feasible alternative to more traditional aerobic exercise modalities for middle-aged and older adults [2] and can be used to train stepping ability in older adults to reduce the risk of falls [3].

We discuss the results of pilot data showing that exergames are an acceptable technology to older adults for home-based exercise and that a relatively short intervention period using Dance Dance Revolution significantly reduces some measures of fall risk. ***References***: 1. Yardley L. et al. Preventative Medicine, 2008, 47, 554-558; 2. Guderian B. et al. Journal of Sports Medicine and Physical Fitness. 2010, 50(4):436-42; 3. Smith ST et al. British Journal of Sports Medicine. 2011. 45(5),441-5.

Fall preventive exercises: A tailored fall preventive exercise program for older adults

Kroll, Michael[1], Marston Hannah R[1], Delbaere, Kim[2], Eichberg, Sabine[1]

[1]*German Sport University Cologne, Germany;* [2]*University of New South Wales, Australia.*

It is well established that physical activity can decelerate age-related loss of physical function. Furthermore, exercise has a major role to play in the prevention of falls and fall-related risk factors among older people. In addition, active older people who exercise are less likely to develop physical disability, cardiovascular disease, hypertension, type 2 diabetes mellitus and osteoporosis. The iStoppFalls project aims to develop an innovative home-based exercise program for older adults using an information and communication technology (ICT) approach with a core component of both strength and balance exercises. The strength component is inspired on the Otago exercise program, which has proven effectiveness in the context of fall prevention and is also conducted in a home setting. The balance component will be incorporated into the exergame. The level of difficulty of the balance exercises will be increased within the exergame by (1) reducing hand support, (2) reducing base of support, and (3) weight shifting tasks through leaning, knee bending, and stepping. As the iStoppFalls exergame will be conducted in the comfort of people's own homes, built-in safety measures insight the exergame using algorithms to detect falls with the Microsoft Kinect camera will ensure the participants' safety during the exercises. This project provides an active translation of evidence-based approaches to falls prevention by using innovative ICT technologies. The iStoppFalls exergame has the potential to offer people a home-based individualized exercise program that might ultimately also be effective at reducing falls in older adults.

A Senior Mobility Monitor for regularly measuring and evaluating daily life activities and movements

Annegarn, Janneke

Philips Research Europe, Netherlands

The iStoppFalls consortium and project will develop an embedded AAL system that can predict and prevent falls by monitoring mobility-related activities and other risk factors of falls in real-life. The iStoppFalls Senior Mobility Monitor platform (SMM) bases on proven technological validity towards objective assessment of balance function and muscle power.[1] Beyond continuous Fall Risk monitoring, this enables tailoring individualized exercise programs coached by iStoppFalls. The SMM is an inertial sensor system which can be worn as a necklace without restrictions. The SMM has two modes: 1) the daily monitoring mode and 2) the exercise mode. During the daily monitoring mode, the SMM provides solutions for continuously monitoring relevant mobility features of the user. The SMM will detect and evaluate sit-to-stand transfers, which reflects balance function and muscle power. Moreover, the SMM will provide information on the activity profile of the elderly. The SMM reports these mobility features on a daily basis. During the exercise mode, the SMM will be used to improve the fall risk assessment by improving the estimations of body sway during quit

standing and power during sit-to-stand transfers. With the SMM, fall risk assessment and trend analysis of balance capabilities can be performed not only in clinical tests, but also in daily life. Furthermore, this trend analysis provides information on the effect of the training exercises for the daily life of the user, and can give feedback to the training system for user specific tailoring of the exercises. ***Reference***: Zijlstra, W., et al., A body-fixed -sensor-based analysis of power during sit-to-stand movements. Gait and Posture, 2010. 31(2): p. 272-278.

Measurement of balance-related biomechanical variables with video game devices

de Rosario, Helios; Belda, Juanma

Instituto de Biomecanica de Valencia, Spain.

In recent years, the computer and video games industry has experienced an important technology push that has brought to the market devices for enabling new forms of human-machine interaction. This includes motion capture technologies, like accelerometers and markerless optical systems that have long been used in human movement science for research in biomechanics. The low cost of these technologies, and the possibility of integrating them in home-based systems, makes the combination of video games and biomechanical analysis a feasible reality. The iStoppFalls project takes advantage of this opportunity for measuring balance-related biomechanical variables with a Kinect sensor and the Senior Mobility Monitor that will be used for assessing the risk of falling during the interaction of users with the "exergame." One of the challenges of this approach is how to adapt the assessment criteria that depend on high-quality biomechanical measures, to a system that is originally designed for capturing gross movements, with fast and inexpensive resources, but lower precision than laboratory instruments. This problem is solved by a redefinition of the measurement protocols, plus advanced analysis of the variables captured by the video-game sensors, in order to reduce the distance between required and achieved precision. Fall risk assessment criteria that were previously validated in extensive field studies have been adapted to exercises that can be made at home, without supervision or additional instrumentation. A skeleton model with 10 joints has been tracked by Kinect, with joint angles corrected by an extended Kalman filter, in order to achieve kinematic parameters that can be compared with the results of a high-quality photogrammetry system.

Empirical analysis of end-user requirements: Designing ICT artifacts for the elderly exercising at home

Meurer, Johanna; Schöning, Sima; Stein, Martin; Wieching, Rainer

University Siegen, Germany.

We want to present first insight of designing community-oriented exergames for elderlies to motivate them to use fall preventive exercise training at home over a longer period of time. Older adults are often reluctant to use ICT systems in their homes, but fall preventive exercises need to be performed at least 3 times a week for 6 months to be effective[1]. Thus, motivation and compliance plays a crucial role in this setting and ICT systems can provide very good support, if they are adjusted to the needs of the elderly end-users. End-user needs assessments were performed by participatory design sessions with end-users for discussion and idea generation by using market available input/output devices in order to develop user settings and scenarios for primary (exercising older adults at home) and secondary (care givers and relatives) end users. Implications based on empirical interviews[2] and workshops were retrieved from 17 users from Germany and Spain so far. We build mock-ups that

illustrate our design idea of that elders might be interested in online communities while playing. Discussing the mock-up and the underlying assumptions with the elderly people in a participatory design workshop, however, showed that they have another perspective on this topic. For them, the design should focus on the necessary features to exercise fall preventive training in the most effective and efficient way instead of looking on nice-to-have community features. In this symposium, we want to discuss, how to deal with this different perspectives in participatory design and if and how community approaches could support motivation of older people to play fall preventive exergames. ***References***: 1. Gillespie, L., Robertson, M., Gillespie, W., Lamb, S., Gates, S., Cumming, R. et al. (2010). Interventions for preventing falls in older people living in the community. Cochrane Database of Systematic Reviews (Online) (2), CD007146; 2. Mayring, P. 2007. Qualitative Inhaltsanalyse. Grundlagen und Techniken (9. Auflage, erste Auflage 1983). Weinheim: Deutscher Studien Verlag, 2007.

Modern fall prediction algorithms: Self-adaptive exercise training plans based on fall related data analysed over time

Drobics, Mario; Ejupi, Andreas; Kreiner, Karl

AIT Austrian Institute of Technology GmbH, Austria.

To provide individual fall-prevention training plans within the project iStoppFalls it is necessary to assess the individual fall risk and training progress of each user in frequent periods. In conventional approaches for fall risk prediction, assessments are conducted in a clinical environment, supervised by a physician. Regular repetitions of the assessments are necessary to monitor the progress of the patient and to adapt the intervention strategy. This is very time consuming (for the patient and the physician) and thus expensive. Additional information, such as the daily activity of a person, can normally not be considered. In the project iStoppFalls, the risk assessments are conducted at the beginning and in regular intervals further on. These assessments are automated and can be done by the older adults in their own homes. Based on these risk assessments, an individual training plan is provided. As a baseline progression of the exercises will be increased linearly, based on the individual performance of the user and the repeated assessments, which guarantee a constant and realistic judgment of the performance of the user. This baseline is further modified based on an automatic analysis of the risk assessment data as well as data captured during the training sessions (duration, quality of execution, etc.) and data on the daily activity of the users (activity level over time, sit-to-stand time, etc.). To derive the according optimization models the data is analysed by experts during a test phase. They can make suggestions for changing the individual training plans (e.g. if the strength of a person is below average, then he has to do more strengthening exercises) and comment on the reason for their decision. This information is then analysed using statistical and machine learning methods to automate the determination of the individual fall risk and the regular adaption of the training plan to the individual needs.

ISPAPOFF SPECIAL SYMPOSIA: EXERCISE FOR FALLS AND FRACTURES

Invited lecture: Which balance assessment tests are fit for purpose?

Masud, Tash

Nottingham University Hospitals NHS Trust, UK.

The two main basic balance conditions are static balance and dynamic balance and humans employ different strategies to keep the centre of mass between the base of support in order