Mobile Games for Elderly Healthcare

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ABSTRACT
The past decade has seen much progress of computer-based tools for health care management. At the same time, mobile devices have become ubiquitous and offer new and interesting means of interaction. In this project we investigate the use of mobile games for home based elderly care. We concentrate on rehabilitation exercises involving the arm's joints and muscles, employing accelerometers to measure and give feedback to players. We discuss the design and evaluation of two such games, Bowling and Penguin Toss. A pilot study suggests that the two games are an effective means for performing range of motion exercises, but that usability depends a lot on the fluency of the interaction during the game. A purely gesture based gameplay seems to be more natural and more enjoyable for the players.

Categories and Subject Descriptors
J.3 [**Life and Medical Sciences**]: Health

General Terms
Design, Experimentation, Human Factors

Keywords
Mobile phone games, iPhone, telecare, accelerometer, exercise therapy, elderly users

1. INTRODUCTION
In the past decade, computer-based tools have been used increasingly for managing healthcare problems in developed countries. These tools include telemedicine, computerized patient records, and other technologies for diagnosis and surgery planning. A lot of these technological developments were concentrated on improving clinical and administrative operations. However, a large amount of cost is incurred for patients who are immobile, requiring healthcare services such as regular check-ups to be done at their home.

With the rise of mobile devices such as cellphones and handheld computers, these technologies are becoming more ubiquitous and their increasing computational power enables us to achieve more complicated tasks remotely from our house and office. Using these devices, different healthcare services, such as education, rehabilitation, and monitoring, can be performed away from hospitals or senior facilities, which decreases the cost that is required for patients with mobility difficulties.

Studies suggest that virtual worlds and healthcare games have the potential to improve healthcare support by increasing players' engagement and education in this area. Nowadays a majority of households play some forms of digital games. By using people's interest in digital games, exercising games can make people more proactive in managing their health and enable health monitoring. Wii Fit is the epitome of a more healthcare oriented type of game available in the market, providing players with an entertaining way of doing exercises. The Wii is currently being used by many rehabilitation centres, to encourage patients to do more exercises while supporting their rehabilitation processes [1,2].

By contrast, mobile devices such as Apple's iPhone and iPod Touch have the advantage that they are more mobile than any other gaming consoles, which enables us to use them in any place at any time. They are ideally suited for developing innovative health monitoring and support tools due to their mobility. Busy people who are always on the run as well as people who are limited in their mobility such as elderlies would both benefit. Another advantage of such mobile devices is their support for direct input through touch screens and accelerometers. These two components allow us to design user interfaces for people that can be operated using their fingers, or rotating and moving the device. Such natural input has been found advantageous for telehealthcare, as mouse and keyboard are often conceived as obstacles [3].

The work presented here is part of a larger research project that is investigating the use of computer-based technologies for effective and affordable home healthcare. In this project, research is done on the development of health monitoring and rehabilitation tools for the iPhone and the iPodTouch. In particular, the aim is to explore their capabilities of providing a usable interface and supporting rehabilitation exercises. Section 2 discusses some important related work from telehealthcare. Section 3 describes the design of two mobile healthcare games, Bowling and Penguin Toss. Section 4 describes evaluation results for these two games, and Section 5 concludes the paper.

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2. RELATED WORK

There are various research efforts made in exploring elderly's interest in digital games. Examples of these include studies about the appeal of video games for elderlies by Aison et al. [4], and about digital game design for elderlies by Ijsselsteijn et al. [5].

Compared to younger gamers, elderly users are more interested in playing games with a perceived meaningful purpose, e.g. improving motor skills or social and educational skills [4]. Aison et al. also suggested that there is a strong correlation between elderlies' success in using technology, and their subjective preference in that piece of technology. This means that games designed for the elderly should be very simple and easy to play. Elderlies tend to choose games based on their familiarity and interest in them. In the experiment that Aison et al. conducted, the majority of participants chose to play games that they had previous experience with, such as golf, or Wheel of Fortune.

The problem with high-fidelity VR equipment is its high cost. Because of the general uncertainty of their capabilities, healthcare professionals are unlikely to invest in them instead of more traditional physiotherapy equipment [6]. However, with the introduction of the Nintendo Wii as a low-cost consumer VR system, the use of VR assisted therapy has increased. Hospitals and elderly homes have started using the Wii system due the interest that it is able to generate from patients, while still being affordable and effective [6].

The Wii measures differences in the applied forces and accelerations of its handheld controller, the Wiimote. These measurements are then used as input to a game, with appropriate visual and auditive feedback. It has games that resemble real-world sports such as tennis, golf, baseball, boxing, and fishing. The games require movements that are similar to those in the real-world equivalents, rather than traditional keyboard and mouse inputs, which are known to be problematic in healthcare systems [3].

With the elderly population growing rapidly, age related chronic diseases are on the rise worldwide [7]. In this project, we are concerned with diseases that are related to joints and muscles, such as arthritis and osteoporosis. They are often diagnosed through physical examination with the patients. Our two healthcare games take physical measurements that aid in finding the difficulties players have with executing moves with their joints and muscles.

Our games are trying to fulfill two purposes at once: therapy and monitoring. Current medical practice indicates that this is feasible, as physical therapy for arthritis patients is often done in a similar fashion as diagnosis during the rehabilitation process. Patients are asked to perform different movements using different joints. In each movement, the movement of the joint is measured and recorded to compare and analyze the joint's *range of motion* (ROM). The ROM is the angular range that the specified joint can move to its full potential. It is usually measured with a goniometer, which measures the angle of a limb at a joint.

Our aim is also to make games more appealing to elderlies in order to make them more proactive in doing exercises regularly. The related work shows us that the game design should focus on what elderlies have some interest in, by choosing games which elderlies are already familiar with.

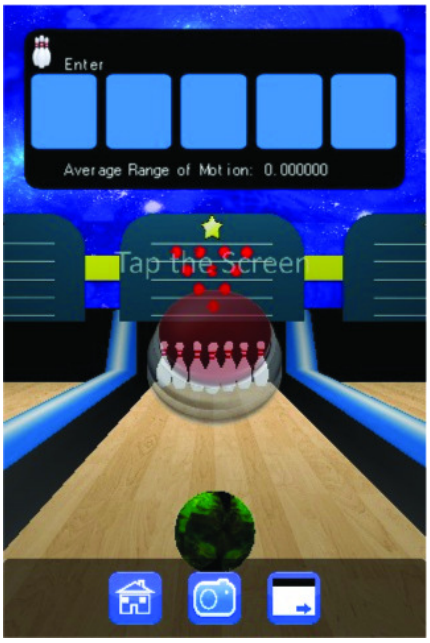

Figure 1. Screenshot of the Bowling game.

3. GAME DESIGN

The iPhone and iPod Touch were chosen due to their popularity amongst consumers, and also due to the large community of application and game developers for these devices. The devices have an integrated accelerometer and a multi-touch screen. Additionally, the iPhones have a built-in camera and an electronic compass. With the accelerometer, we can create games that can be controlled by swinging or flicking their device, enabling us to design exercise games similar to those on the Wii. A compass can potentially be used to set a target location in a game, e.g. for checking if a virtual ball was thrown in a specific direction.

The accelerometer is used intensely in our games as the main input from the player. There are three axes that the accelerometer works in. Movement along each of the axes can be detected, and measured in variables x, y and z as a change in velocity over time, which is the acceleration in a linear path relative to the device. As our games involve acceleration gestures while holding the device, it is important that players use a hand strap. If the device is secured like this, inadvertent release of the device does not cause any harm or damage.

Apart from measuring linear acceleration, the accelerometer also lets us measure the pitch and roll of the device. Roll corresponds to the rotation around the vertical Y axis, and pitch corresponds to the rotation around the horizontal X axis. iPhone and iPod Touch do not support yaw, i.e. rotation around the Z axis. Instead, the Z value varies: when the device faces up, the Z value becomes -1.0, and when the device faces down, the Z value becomes 1.0.

3.1 Bowling

This game is designed to help the player train and improve the motion of the upper limb, i.e. mostly the shoulder. When the player enters the game, a bowling arena is shown, as can be seen in Figure 1. The rules strictly follow the real bowling game, so

that elderly people can enjoy playing a familiar game without having to go to a bowling arena on their own. In essence, the game is played by swinging the phone using the shoulder, just like what people would do in a real bowling game.

The interface of the game is designed to suit elderlies' needs, including those who have little computer or gaming experience. Instructions are provided in-game, so the player is told how to hold the phone, etc. Apart from the swinging, the game can be operated by using only one main button in the middle of the screen, displaying simplistic instruction such as "Tap the Screen", "Confirm", "Tap and Swing".

The main button will flash when input is required, so that it attracts the attention of the player. Important information is displayed using a bigger font, to ensure that it is easy to read. The game records the raw accelerometer values for each swing. The range of motion is calculated by determining the start and end orientation vectors, i.e. the vectors at the beginning and end of a swing.

3.2 Penguin Toss

This game is designed to help elderly people exercise their arms and strengthen their biceps, triceps and forearms. The aim of the game is to throw a penguin into one of two hoops, by flexing and extending the elbow joint in a throw-like movement. That is, the forearm is brought close to the biceps and then stretched outwards while holding the phone in the hand. This movement is common in weight exercises such as triceps extensions and curls. Since the speed and direction in which the penguin travels in projectile motion depends on the actual speed and direction the players swing their arms, players can exercise their arm strength and the coordination of their arm movements. A screenshot is shown in Figure 2.

After a splash screen, an introductory page appears that explains to the player how to play the game. The game begins straight away after the player taps the screen. Once the game is running, the game can be played using purely gesture based interaction.

The game gives feedback and encourages players to improve their speed, ROM and accuracy. The penguin can be thrown towards either of two hoops. The player scores one point if the penguin enters the left hoop, which is closer to the penguin, and three points if the penguin enters the right hoop, which is farther away and hence more difficult to hit. The ROM is measured following the same principle as in Bowling. The ROM of an elbow is around 145 degrees. If the ROM is between 90 and 145 degrees, the display shows "Stretch a bit more!", and if it exceeds 145 degrees it shows "Well done!".

4. EVALUATION

The usability, effectiveness and appeal of the two healthcare mobile games were evaluated experimentally with the help of 5 subjects aged from 50 to 63, and 16 subjects aged from 11 to 37. Because of the small sample size, the results from these experiments are only indicative and serve as a pilot study. In particular, more elderly participants are necessary to confirm that the results are valid for our target group.

Figure 2. Screenshot of the Penguin Toss game.

4.1 Usability

The time the subjects took to understand how to play the games was recorded. It was operationalized as the time until a participant had successfully hit three targets. Prior to this, the subjects were free to try the games on their own; external help in understanding the games was not given to maintain this as a fair test for usability.

24% of the subjects understood how to play Bowling and 57% of the subjects understood how to play Penguin Toss in less than three minutes. All participants took less than 10 minutes to understand the games. This is an indication that the Penguin Toss is moderately easy to understand, but that it is a lot harder to understand the Bowling game.

This has to do with the inherent complexity of the Bowling game as compared to Penguin Toss, but also with the complexity of the interaction. While Penguin Toss can be played almost solely gesture based, Bowling requires frequent touch screen interaction during a game, e.g. before each swing. In order to make the interaction in Bowling more natural, the gesture recognizer should be improved so that no touch screen interaction during the running game is necessary.

4.2 Effectiveness

The second objective of the user study was to evaluate whether patients do correct body movements when playing the game, or whether they employ shortcuts that diminish the exercise benefits of the games. The subjects were asked to play five rounds of each game. Each round is equivalent to one throw or bowl in the respective game. During each round their arm and body movements were observed, classified and recorded together with their scores and measured ROM.

Most participants were moving their arms considerably during the games. In Bowling, 85% of the subjects moved the whole arm, 11% moved the lower arm, and 4% moved only the wrist. In

Penguin Toss, 79% of the subjects moved the whole arm and 26% moved the lower arm only. It was observed that people tend to swing their arms more widely when playing Bowling, whereas they tend to swing their arms around the elbow more while playing Penguin Toss.

For Bowling, there is a great variation of lower body and trunk movements. 33% of the subjects took steps, 20% rotated only their upper body, 25% moved the lower body, and 22% did not move their lower body at all. The game could reward lower body and trunk movements more, thereby encouraging the players to more exercise. For example, translations along the z-axis could be measured as an indication of participants leaning forward or making steps.

During Penguin Toss, only 5% of the subjects took steps, 29% rotated their upper body, 5% rotated the lower body, and 61% did not move their lower body or trunk at all. Generally, the participants' conceptions of "tossing" do not involve lower body movements, as opposed to "bowling". Since the game targets primarily the ROM of the elbow joint, this is not a problem.

It was observed that when the player's ROM was measured only below 45 degrees, then this was mainly caused by measurement errors. The gesture recognizers had difficulties in cases where participants were swinging too quickly, or executing unintended motion gestures. For example, one participant who constantly got a ROM measurement below 45 degrees always swung backwards after a normal swing. This caused the end vector to be near the start vector used for range of motion calculation. However, in our experiments such recognition errors happened only infrequently in odd cases. Further studies have to be done to see how frequently such errors occur in practice. Also, by analyzing these odd cases we hope to improve our gesture recognizers for future studies.

At the end of each experiment, participants were asked to rate their perceived physical exhaustion during the game on a scale between -4 and 4. There is a great variance between participants, which is probably due to different fitness levels and subjective bias. Penguin Toss was generally perceived as more physically challenging than Bowling. The sum of the ratings for Penguin Toss is 10, but only -1 for Bowling. This indicates that the Tossing game has a greater potential for physical training.

The result of tossing being more exhausting than bowling seems to contradict the results about the observed movements and measured ROMs. It was observed that the subjects moved more and had a larger ROM when playing Bowling. This can be explained by the physiology of the respective movements: during bowling, participants can initially pivot their arm around the shoulder joint using the force of gravity, similar to a swing. The tossing movement works mostly against gravity, lifting and holding the arm above the shoulder joint. Exercises in which the arms are held up are also known to be more taxing for the cardiovascular system: the blood has to be pumped upwards into the arm, rather than flowing down from the shoulder.

5. CONCLUSION

In this project, we have implemented and evaluated two healthcare games on mobile devices. The games, Bowling and Penguin Toss, are very simple, addressing range of motion rehabilitation of the shoulder and elbow joints. One of the main challenges of such games is the development of gesture recognizers for the exercise movements. We developed recognizers for the bowling and tossing exercises, employing data from the accelerometers in the mobile devices. Our experience shows that for simple target movements recognizers can be developed fairly easily, but that recognition can be prone to errors. The main difficulty lies in detecting the start and end points of a gesture.

Our results indicate that simple gesture based games are moderately easy to understand, but that their usability is strongly influenced by the complexity and fluency of the gameplay. Despite being harder and thus potentially less motivating, the Penguin Toss game got a lot higher enjoyment ratings than the Bowling game. This seems to be due to its purely gesture based interaction during gameplay, that allows players to just play and ignore the more tedious interaction with the touch screen.

Our classifications of movements and ROM measurements during the experiments indicate that the games are effective in exercising a player's ROM. The games have done well in making players do full swings and tosses using their shoulder and elbow joints. Improvements here could be achieved by adjusting the scoring system, for example so that players are encouraged to use also their lower body to get additional benefit from the exercise.

Overall, this project indicates that mobile healthcare games for elderly are feasible as a rehabilitation and exercise tool. However, due to the limitations of our study, e.g. the demographics and size of the sample, is premature to make such conclusions. We will continue to develop the healthcare games and try to evaluate the games in a more realistic setting with a more realistic group of users in the future.

6. REFERENCES

[1] "Nintendo World Report - News Article: UK Hospital Adopts Wii Fit to Rehabilitate Amputees," Jan. 2009. http://www.nintendoworldreport.com/newsArt.cfm?artid=17484

[2] R.C.V. Loureiro, D. Valentine, B. Lamperd, C. Collin, and W.S. Harwin, "Gaming and Social Interactions in the Rehabilitation of Brain Injuries: A Pilot Study with the Nintendo Wii Console," Designing Inclusive Interactions, 2010, pp. 219-228.

[3] D.R. Kaufman, V.L. Patel, C. Hilliman, P.C. Morin, J. Pevzner, R.S. Weinstock, R. Goland, S. Shea, and J. Starren, "Usability in the real world: assessing medical information technologies in patients' homes," Journal of Biomedical Informatics, vol. 36, 2003, pp. 45-60.

[4] C. Aison, G. Davis, J. Milner, and E. Targum, "Appeal and Interest of Video Game Use Among the Elderly," Harvard Graduate School of Education (May 2002), i-28. 2002.

[5] W. Ijsselsteijn, H.H. Nap, Y. de Kort, and K. Poels, "Digital game design for elderly users," Proceedings of the 2007 conference on Future Play, 2007, pp. 17-22.

[6] "Therapists prescribe video games to assist recovery," Briefings on Outpatient Rehab Reimbursement and Regulations, vol. 13, 2008.

[7] World Health Organization, "Active Ageing - a policy framework," 2002, pp. 12-23.