Exergames for Elderly in Ambient Assisted Living Environments

Determinants for Performance Technology Acceptance

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Abstract. Ambient Assisted Living (AAL) environments offer a solution to the challenges of the demographic change by supporting elderly and chronically ill people inside their own home environments. Serious and pervasive games can change people's attitudes and can promote healthy behavior. However, both concepts are rarely combined and the integration of both concepts is insufficiently explored. We present a user study (n = 64) of an Exergame for AAL environments with the research foci performance and acceptance. Age is the predominant factor for performance, while the intention to use is determined by gaming frequency. Neither technical self-efficacy nor age had considerable influence on these measures. However, the interaction with the game had a considerable positive effect on the participant's perceived health and pain. The study shows that Exergames in AAL environments are a viable solution to support the autonomy and independence of people in an aging society.

Keywords: Serious games · Exergames · Ambient Assisted Living (AAL) · Self-Efficacy · Acceptance · User experience · Gaming frequency

1 Introduction and Related Work

Increased life expectancy in many western countries leads to a demographic change that will have a tremendous impact on the healthcare system. According to current predictions, a shrinking working population will have to support a growing number of retirees: In Europe, the share of people aged 65 years and over is projected to increase by more than 50 % from 17.1 % in 2008 to 30 % in 2060 [1]. Likewise, the share of people older than 80 years is projected to triple in the same timeframe. This will stress the healthcare systems significantly as the likelihood of chronic illnesses increases with age [2]. In contrast, the per capita expenses for healthcare is declining in many western societies [3]. Accordingly, in the near future less people will contribute to a healthcare system that more people depend on.

Two solutions alleviate the rising costs of the healthcare systems: First, Ambient Assisted Living (AAL) technologies that are integrated into the home environments of

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elderly, chronically ill, or disabled people. These technologies can assist in several every day tasks and facilitate a comfortable and independent life in one's own home [4, 5]. Second, serious games can change people's attitudes towards health, can promote healthy behavior, and can increase physical agility [6–9].

Additionally, it is possible to combine these two solutions as serious games can be offered in AAL environments. Serious games and particularly Exergames harness the power of the psychological Premack principle [10]: They interlink physical activities (which are often perceived as unpleasant) with games (which are usually perceived as pleasant and entertaining). Specifically, exercise games require physical activities and body movements to progress within a game. Still, to unfold the potential positive effects users must utilize them frequently and on a regular basis. However, the individual factors influencing perceived usability, intention to use, and performance within serious Exergames in Ambient Assisted Living environments have been insufficiently explored so far. To fill this void, we present a serious game for AAL environments and a summative user study that detangles the influence of user factors on performance, acceptance, and perceived health status.

2 Game Concept and Development

The exercise game is designed to fit into our Ambient Assisted Living room that is designed as a research space to understand if and under which conditions users would adopt ambient assisted technology [11]. The room is a simulacrum of a comfortable 25 m^2 living room, with a large window, two couches, and two bookshelves, that is transparently augmented by several input and output devices such as a sensory floor for detecting falls, a Kinect-based movement and gesture detection system, and an infrared camera to check the inhabitant's health status. Also, the room is furnished with a wall-sized multi-touch display (4.8×2.4 m^2, see [12]).

The game itself is situated in a virtual garden environment that is presented on the large wall (see Fig. 1). The user's task is to pass through a series of consecutive levels with increasing complexity in which he or she collects different fruits and vegetables by performing different gestures with his or her body. A Microsoft Kinect™ sensor tracks the user's movements and the game evaluates whether the gestures are performed correctly. For example, in the first level the user's task is to pick apples from a tree by raising one arm. In the following level, another type of fruit and movement are added, in this case pears that require a grab and hold gesture. All required gestures within the game were developed in cooperation with medical professionals (orthopedists and ergo therapists) to ensure that essential and often neglected body movements are exercised during the game [6, 13].

A previous study evaluated an initial prototype of the game with 71 participants (between 20 and 86 years of age) in a doctor's office [6]. Although the performance within the game was much higher for younger users, users from all ages liked the game and expressed the wish to use it frequently. While interacting with the game increased the perceived physical exertion, the perceived pain levels decreased.

The second prototype was refined to reflect the user's feedback from the initial user study and was then integrated into the Ambient Assisted Living room (see Fig. 1).

Fig. 1. Prototype of the Exergame in an AAL environment.

The following section describes the user study that was carried out to evaluate the second iteration of the game prototype.

3 Method

The exploratory study investigates how older adults interact with the exercise game integrated in the ambient assisted home environment and addresses three main research questions: First, what user factors contribute to performance within the Exergame? Second, which factors explain the intention to use the game? Third, has the game an impact on the perceived health of the users?

Procedure: The participants played the first three levels of the game in RWTH Aachen University's ambient assisted living lab (eHealth lab). Each of the three levels lasted 120 s. Before the interaction with the game a survey assessed the explanatory variables. After the game the subjective preferences regarding the game were measured. Log files captured the participants' performance within the game.

Explanatory variables (control variables) for modeling user factors were *self-efficacy in interacting with technology (SET)*, *need for achievement (NArch)*, *gaming frequency (GF)*, *gender*, and *age*. *Self-efficacy in interaction with technology* [14] explains large portions of effectivity, efficiency, and user-satisfaction in interaction with information and communication technology and plays a mayor role for elderly interacting with technology [15]. *Gaming frequency* is measured as the average playing frequency of games (card, board, and movement games with and without computers). *Need for achievement* measures the desire to reach difficult and distant goals in domains such as sports or in the job [16]. The inclination towards games might transfer towards the movement games and people with high need for achievement might feel incited by the game.

Depended variables were *performance* within the game (measured as average number of *fruits/vegetables* collected in the first three levels), *perceived pain* and *perceived exertion* (difference before and after using the game), as well as *behavioral intention (BI)* from the Unified Theory of Acceptance and Use of Technology (UTAUT2) model [17] as the intention to use such a game in the future. The UTAUT2 model explains the adoption of technology depending on a set of promoting and hindering factors. *Perceived exertion* is measured before and after the game on a reduced Borg scale [18]. The scale is subjective, yet it correlates strongly with the heart rate ($r > .8$).

Except for in-game *performance*, all variables are surveyed on 6-point Likert scales. The data is analyzed using χ^2-tests, univariate analyses of variance with repeated-measures (repeated-measures ANOVA), and stepwise multiple linear regressions. Type I error rate (level of significance) is set to $\alpha = .05$. Type II error rate (power) is set to $(1 - \beta) = .8$. For linear regressions only valid models with no or moderate VIF are reported. The explained variance is reported as corrected r^2-values.

In total, 64 people have participated in the study (32 male, 32 female). The *age* of the participants ranged from 17 to 85 years ($M = 43.2$, $\sigma = 19.6$). 26 % reported chronic illnesses, mainly asthma, diabetes, cardiovascular diseases, but also depressions. To analyze age-related effects with factorial methods, the sample was divided into the groups *young* ($M = 25.7$, $\sigma = 4.5$) and *old* ($M = 60.6$, $\sigma = 11.4$). *Gender* was equally distributed among both age groups ($\chi^2(1, N = 64) = .250$, $p = .617 > .05$, n.s.).

4 Results

The results are presented as follows: First, the determinants for *performance* are reported. Second, the factors explaining the *behavioral intention* are presented. Finally, the effect of the game on *perceived pain* and *exertion* are shown.

4.1 Determinants for Performance

To identify factors explaining *performance*, a multiple regression analysis with the dependent variable *performance* and the independent variables a*ge*, *gaming frequency, need for achievement, perceived pain*, and *self-efficacy in interacting with technology* was carried out. The regression yielded three significant models: The first model, with the factor a*ge*, explains $r^2 = .508$ (50 %) of the variance in *performance* ($F(1, 57) = 58.960$, $p < .01$). The second model (*Age + NArch*) explains an additional 5 % ($r^2 = .559$) of the *performance* ($F(2, 56) = 37.819$, $p < .01$). The third and last model (*Age + NArch + Gender*) contributes an extra 4 % ($r^2 = .605$, $F(3, 55) = 30.671$, $p < .01$).

4.2 Determinants for Usage Intention (Behavioral Intention)

In addition to the previous set of independent variables, the users' average performance is considered in the regression model for *behavioral intention (BI)* from the UTAUT2 model. This regression yielded two significant models: The first, with the single factor *gaming frequency*, explains $r^2 = .206$ (20 %) of the *BI* ($F(1, 57) = 16.059$, $p < .01$). The second model, with *gaming frequency* and *performance*, explains an additional 6 % ($r^2 = .257$, $F(2, 56) = 11.041$, $p < .01$) of the *BI*.

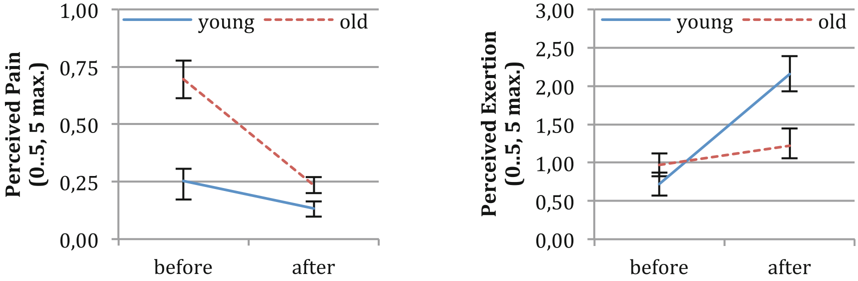

Fig. 2. Change of perceived pain (left) and perceived exertion (right).

4.3 Effect on Perceived Exertion and Perceived Pain

While the levels of *perceived exertion* increased significantly during the experiment ($F(1, 62) = 14.571$, $p < .001$, $\eta^2 = .190$), the levels of *perceived pain* decreased ($F(1, 62) = 118.543$, $p < .001$, $\eta^2 = .230$). For both measures a significant interaction with *age* is observed. (*Exertion*: $F(1, 62) = 7.215$, $p = .009$, $\eta^2 = .104$, *Pain*: $F(1, 62) = 6.322$, $p = .025$, $\eta^2 = .093$). Specifically, younger users reported higher levels of *perceived exertion* while older users reported stronger reductions in their *perceived pain* levels (see Fig. 2, left and right).

5 Discussion

The results of the user study fit well into the current research landscape. The study affirmed that age is the strongest predictor for performance within the game and that psychomotoric performance decreases with age. The remarkable revelation, however, is that no other personality factor has a considerable influence on performance. Game performance is only weakly affected by need for achievement and gender. Additionally, neither gaming frequency nor self-efficacy in interacting with technology has an influence on performance. The intention to use the serious game (Behavioral Intention) is influenced only by the current gaming frequency of the participants. This finding has both negative and positive aspects that need to be addressed in future research: On the negative side, the game seems to be only attractive to people who are already inclined to gaming and who play games on a regular basis. Therefore, people unattached to games might not use Exergames in ambient assisted living environments. They cannot profit from the benefits of these and have to find other ways to sustain their physical fitness. On the positive side, the intention to use Exergames in ambient assisted living environments is neither affected by age, need for achievement, nor by self-efficacy in interacting with technology. Consequently, Exergames seem to be a ubiquitous solution to increase the physical fitness of people living in AAL environments, at least if they like to play games.

Most importantly, even the short interaction with the Exergame motivated our test users to vigorously engage in physical activity. The short-term effect was a reduced perceived pain (especially for elderly) while a possible long-term effect might be the prevention of a rise of cardio-vascular diseases in elderly.

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