Serious Games for Cognitive Training in Ambient Assisted Living Environments – A Technology Acceptance Perspective

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Abstract. Two technology trends address the rising costs of healthcare systems in aging societies: Serious Games for Healthcare and Ambient Assisted Living Environments. Surprisingly, these concepts are rarely combined and the users' perception and use of Serious Games in Ambient Assisted Living environments is insufficiently understood. We present the evaluation of a serious game for stimulating cognitive abilities for elderly with regard to technology acceptance (based on the UTAUT2 model), performance and preference for an interaction device (tablet, table, wall). The results suggest that acceptance of serious games is independent of gender, technical expertise, gaming habits, and only weakly influenced by age. Determinants for acceptance are perceived fun and the feeling that the users can make playing the game a habit. Performance within the game is explained by age and previous gaming experience. All investigated interaction devices were rated as useful and easy to learn, although the wall-sized display had lower approval levels. The article concludes with guidelines for successfully introducing serious games for healthcare to residents in ambient assisted living environments.

Keywords: Serious games for healthcare · Ubiquitous computing · Ambient assisted living · Technology acceptance · Design for elderly

1 Introduction

Increased life expectancy and declining birth rates in many western societies lead to a demographic change that has a tremendous impact on the healthcare system. The share of people aged 65 years and older is projected to rise from 17 % in 2008 to 30 % in the year 2060 [1]. This influences the financing of the healthcare systems, as the number of jobholders who cover dependent elderly persons is declining from 3.2:1 to 1.85:1 within the next 40 years. Additionally, the number of people 80 + is expected to nearly triple within the same period. As chronic illnesses and diseases increases with age [2] the declining number of jobholders need to cover even higher expense for geriatric care. In contrast, the per capita expenses in the healthcare system is declining in OECD countries [3] and therefore less money is available for caregiving and offering therapy for older, handicapped or chronically ill persons.

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Two solutions address the rising costs of the healthcare systems: Ambient Assisted Living (AAL) environments and Serious Games for Healthcare (SG4HC). The former aim at enhancing the quality of life of elderly or handicapped people through supportive technology in the living environment, while the latter harnesses the ludic drive to make physical and cognitive exercises for training and rehabilitation fun and desirable. Serious games can easily be offered in AAL environments. Yet, these games can only unfold positive effects on mental or physical health and well being, if they are used frequently and periodically. This adherence depends on a number of system factors (e.g., feedback accuracy, latency, usability, …), as well as personality factors (e.g., age, gender, expertise, trust, …) that are not sufficiently understood. To address this void, this work evaluates a prototypic serious game for ambient assisted living environments that aims at improving cognitive functioning. This summative user study investigates the interrelationship of user diversity and system design on performance, perceived usability and acceptance of serious games for healthcare.

2 Related Work

This section gives an overview about current approaches for Ambient Assisted Living, Serious Games for Healthcare, and Technology Acceptance research.

2.1 Ubiquitous Computing and Ambient Assisted Living

In 1991 Marc Weiser predicted a future in which computers shrink in size and grow in number, capacity, and capability. Weiser envisioned “smart environments” in which numerous computers are seamlessly integrated into physical environments and eventually converge with everyday objects [4]. He envisioned that computers will work unnoticeable and enhance the quality of work and life and that using them will be “as refreshing as taking a walk in the woods”.

Ambient Assisted Living (AAL) takes up the idea of ubiquitous and smart environments to support elderly, handicapped or chronically ill people: Smart information and communication technology integrated in personal home environments is designed to support an independent and self-determined life style [5–7]. AAL can support people in various ways: First, they can offer emergency assistance by preventing or detecting acute situations (e.g., strokes, heart attacks, when a persons falls, …). Second, they can enhance the autonomy of a person by supporting cleaning, medication or even shopping, or by offering trainings and rehabilitation measures. Third, they can increase comfort through home automation or by infotainment offerings.

Although AAL is increasingly recognized from politics and research institutions as a humane and viable solution to meet the challenges caused by the demographic change [8], many fundamental ethical, social and legal questions have not yet been sufficiently answered: The social implications of these technologies at home and the user’s requirements regarding privacy and trust are insufficiently understood issues [9, 10]. Nevertheless, understanding the user’s thoughts, concerns, and requirements is a significant research domain and critical for the success of AAL [11, 12].

To understand how people would live in and use these technology-enhanced supportive environments and to capture their requirements, prototypic living labs are constructed and innovative technologies and services are evaluated. The present study was carried out in RWTH Aachen University's *eHealth Lab* [13]. The specifications of the lab are given in the description of the experiment.

2.2 Serious Games

Serious Games are not primarily focused on entertainment, but on other goals such as to train or educate [14]. Michael and Chen define a "serious game is a game in which education (in its various forms) is the primary goal, rather than entertainment" [15]. The effectiveness of serious games build upon the Premack principle [16]: The occurrence of an unlikely activity will increase if coupled with a likely activity. Hence, unlikely and inconvenient activities, such as regular physical or cognitive training, can be linked with likely and pleasant activities such as playing games. Playing games is part of the human nature and many people play on a regular basis [17], hence they are suitable to link with exercising or training which are often undesired activities.

In the healthcare domain best-known examples of serious games are Exergames (exercise games) that use the users' body movements as input. Exergames are already successfully used in rehabilitation [18] or to promote physical fitness [19, 20].

Yet, the field of cognitive training is still insufficiently explored. Although the suitability, effectiveness and necessity of game-mediated cognitive training is often cited from the medical point of view [21, 22] and commercial games for cognitive training are readily available at video game stores (e.g. *Brain Boost: Beta Wave* for Nintendo DS, *Body and Brain Connection* for Microsoft Xbox 360 or *Smart As…* for Sony PlayStation Vita), little is known about how these games can be successfully integrated in AAL environments and how they should be designed to be accepted and used by a diverse population of users.

2.3 Technology Acceptance Research

The goal of technology acceptance research is to predict if users will adopt and adhere to a technology – such as eHealth technology or Serious Games for Healthcare – and to identify the factors that influence this process. It has its roots in the Ajzen and Fishbein's *Theory of Reasons Action (TRA)* [23] and *Theory of Planned Behavior (TPB)* [24]. These theories state that an individual's behavior is based on his or her intention to perform the behavior. This *behavioral intention* is formed by the individual's attitudes, subjective beliefs, and (in TPB) self-efficacy towards the behavior. Based on these models from behavioral psychology, Davis developed the well-known *Technology Acceptance Model (TAM)* that predicts the usage intention and later use of software applications [25]. In TAM *perceived usefulness*, *perceived ease of use*, and the *attitude towards using* the software determines the intention to use the software. As in TRA and TPB, the intention to use the software is closely related to the later actual use. Hence, factors contributing to usage intention also explain later use.

Davis' Technology Acceptance Model – originally designed to predict software usage in professional environments – continuously evolved to describe software and technology adoption processes in different contexts (e.g., for consumer electronics or voluntary software use) or with a refined set of explaining variables. A prominent example that this study builds on is the *Unified Theory of Acceptance and Use of Technology 2 (UTAUT2)* by Venkatesh et al. [26]. UTAUT2 is designed to predict the adoption of technologies outside work environments, i.e., in situations where the use is voluntary and not driven by work requirements. In UTAUT2 seven factors predict the (voluntary) adoption of a technology: *Performance expectancy* models the user's perceived benefit from using the technology through increased performance or richer possibilities. *Effort expectancy* addresses a persons' perceived effort in learning how to use the technology. *Facilitating conditions* captures the individual's perception of whether he or she is able to acquire help by others, if obstacles hinder using the technology. *Social influence* meters the influence of family, friends and colleagues on the adoption process, e.g. if using the technology is encouraged or admired by others. *Hedonic motivation* refers to the fun and pleasure the individual perceives while using the technology. *Price-value* models the tradeoff between the individual's financial investment in the technology and the perceived benefit from using it. *Habit* captures the user's perception whether he or she can make using the technology a routine. Overall, the UTAUT2 model can predict about 75 % of the variance of behavioral intention and over 50 % of variance of later use of a technology. UTAUT2 is therefore a suitable model to predict the adoption of technologies where the use is voluntary and not required by superiors or – in the case of medical technology – physicians.

2.4 Combination of These Domains

The combination of the three domains Serious Games for Healthcare, Ambient Assisted Living, and Technology Acceptance Research is mainly unexplored and a rich and challenging research domain.

A serious exercise game for enhancing the physical fitness and independence of elderly residents in AAL environments was analyzed in [27]. Central findings of the study with 64 participants are that the intention to use the game is explained only by gaming frequency, meaning that people who like to play games have a higher intention to use exercise games to improve their fitness. Usage intention was independent of age, gender, or need for achievement, although these were the best predictors for performance within the game. Regarding the UTAUT2 model, all explaining variables were positively related to the intention to use exercise games. Strongest predictors for an adoption were a person's feeling of making exercising a habit and social inclusion and social encouragement.

It is unclear if these findings from an exercise game are transferable to other game domains. Hence, a game that addresses the cognitive functioning of elderly (retention and planning capabilities) will be evaluated using the same research methodology. The next section outlines the game design, followed by the experimental setup.

3 Game Design and Development

This section outlines the needs of elderly regarding usability and game design, the game design process, and the actual game.

3.1 Game Design Considerations

Facing the growing aging population, one of the major challenges for healthcare systems in the 21st century is to master the demands of an aging society [28, 29]. Healthcare-related technologies become increasingly important. Supporting older adults in keeping an independent life style at home is achievable only by technology that fit into the individual's living spaces, that respects the specific needs and demands of people and their willingness to use and integrate devices into their personal spaces and their personal lives [30]. Currently, most technical interfaces are designed neglecting the needs and abilities of aged users. Aging is connected to a number of changes in sensory, physical, psychomotor and cognitive functioning over the life span [31]. Beyond visibility problems and a decreasing psychomotor ability, one major characteristic of aging is the deceleration of executive functions, i.e., working memory, information processing, and planning of complex tasks [32–34]. Planning competence comprises many cognitive sub skills that have to be executed in parallel and/or consecutively. For example, for preparing meals, users have to memorize the recipe, know which food products are necessary, anticipate the order of food products to be used one after another, and anticipate potential problems and the way they could be solved. Especially in all-day situations, the decreasing planning ability is a serious issue that could be supported in computer-assisted trainings. On the other hand, older users have greater difficulties in handling technical devices [35–37] and face difficulties in learning and using new computer applications. Contrary to current stereotypes, according to which older users are unable or unwilling to learn new technologies, older users are interested in becoming acquainted with novel technology. However, older users do have higher demands on usable interface designs [38].

To build a game that is accepted and used by older adults, the game environment must be designed in line with the wants and needs of this target group. De Schutter has identified three elemental aspects that games must provide to address their interests and preferences [39]: *Connectivity*, *cultivation*, and *contribution*. Connectivity describes that people prefer games in which they can connect with others, friends and family. Hence, games should support multiplayer modes or high-scores. Older adults not only want to be consumers of video games, but also want to cultivate themselves. Despite their age, they are still interested in seeing new places, learning, and gaining knowledge. Contribution is the desire of many people to contribute their knowledge to others. This may be new game content or shared knowledge or personal experiences. Possible game concepts identified by De Schutter include a chef cook game, but also games such as a fashion designer, a travel game, or guessing games.

3.2 The Game Concept

We identified cooking as a promising game scenario because nutrition is an important concern of everyday life and cooking requires certain cognitive skills to produce an enjoyable outcome. In particular it requires good retention capabilities to remember the preparation steps already done and to be done next. In addition a vital executive function in form of planning skills is essential to be able to organize the cooking process. This concept becomes manifest in the name of the game: “Cook It Right”.

In the game players select recipes from a list that he or she wants to reproduce in a virtual kitchen. Before the preparation of meal starts, the player needs to memorize the instructions, as these will not be available later on. The user then starts to produce the outcome on a virtual kitchen worktop, where all the ingredients and required tools are presented. The visual representation of the playing area changes according to the users interactions, which he or she can choose from popups after selecting an ingredient or kitchenware (e.g. after a bread is selected a popup appears that offers to put butter on the bread). Finally, if the user decides that the meal is completed and served on a virtual dish, a result view is shown which contains a rating depending on the time required for the preparation.

Cook It Right fulfills De Schutters three criteria of games for older adults: *Connectivity* is realized in a multiplayer scenario in which two players prepare the meal together. *Cultivation* is accomplished as new recipes can be learned within the interactive game. *Contribution* is satisfied with a recipe designer, where users can provide and design their own favorite recipes that then get played by other users.

3.3 Development Process and Interaction Design

The design and development of the game strictly followed a user-centered and participatory design approach with several iterations of implementation and evaluation phases [40]. The development started with storyboards (see Fig. 1, left) and paper prototypes (see Fig. 1, center) to generate basic ideas of the user interface, its elements and interactions [41]. During these phases fundamental design changes along with a number of minor corrections were made based on the feedback of usability experts and elderly users. In the game the user must combine several ingredients (e.g., water, salt, and flour) and use tools (e.g., blender) to prepare meals or parts of a meal (e.g., pastry). The user selects visible ingredients and tools on the display surface using touch interaction and a context-sensitive menu offers possible actions (e.g., put flour into bowl). For each preparation step a specific time is allocated and multiple parallel tasks had to be synchronized (e.g., dough had to stay in the oven for 2 min, then tomato sauce must be ready; comparable to [33]). The users disliked this timed concept, found it too stressful, and too little game like. Following user’s suggestions, it was changed to be purely turn based and users can interact with the game in their own pace. After the preparation of a meal is finished, a feedback score is presented based on completion time and correctness.

Fig. 1. Stages of the iterative development of *Cook It Right*: Storyboard of the basic game interactions (left), interactive paper prototype (center), game's functional prototype (right)

The overall positive feedback supported the decision to continue the development as a high fidelity and functional software prototype. First, the logic for handling recipes and an extendable recipe pool was developed. We analyzed several recipes and identified a tree-like structure with three entities: *Ingredients*, *tools* and *containers*. In every possible interaction (which we name transitions since a state traversal occurs) a container is involved (e.g., a bowl or a pan). In each step a tool or ingredient is combined with a container. There can be several possible interactions in a certain state for a container: For example, to produce pastry one has to blend water with flour in a bowl and there are two possible paths: First, water can be put into the bowl, then flour is added and the ingredients are blended. Second, flour can be added first, then water is added and both ingredients are blended. Also, some transitions are idempotent, i.e. actions can be executed repeatedly without changing the visual outcome. For example, salt can be added repeatedly without changing the outcome of the dish (contrary to reality were a soup can actually be over salted). These interactions were modeled with an attributed XML structure. The inner vertices of this tree represent containers in a certain state. The leafs represent ingredients or tools, which can be combined with its container. Within the application, this tree structure is used to check possible transitions and to construct the popup menus for presenting possible actions for combining the ingredients. It is also used for checking for completeness and for calculating a final score as performance feedback, once the user has finished cooking by pressing the button “Serve Dish”.

The visual design of this iteration is related to the early paper prototype of the game, as hand-drawn images from the prototyping sessions we used as sprites in the game (see Fig. 1, right).

3.4 The Game's Context: AAL Living Environment

The game is developed as one of several applications in our university's Ambient Assisted Living lab [13]. It resembles a prototypic living room of 25 m^2 with two comfortable couches, a coffee table, bookshelves, and wall pictures. However, the lab is designed for chronically ill or frail elderly people and is equipped with various sensor technology for measuring the residents vital parameters (e.g., blood pressure, temperature, coagulation, and weight) and its attentive sensory floor is able to detect falls.

The living room provides various forms of support to the resident's life. For example, a large display wall can be used as a video link to communicate with friends, relatives, or medical staff, the lights and heating can be controlled via several different devices and from different positions within the room, and music, personal pictures, and videos are easily available.[1]

People can interact with the room through various different devices, ranging from a Kinect-based gesture detection system, through a touch surface embedded in the couch. This allows us as researchers to explore novel interaction devices and interaction techniques together with prospective users in a realistic living context. Within this study, the game *Cook it Right* was delivered and evaluated on three different touch-based interaction devices: A large multitouch wall (4.8×2.4 m^2, see Fig. 2, left) realized using rear projection on the surface elements, a multitouch display embedded in a off-the-shelf coffee table from a Swedish furniture store (47.5×29.9 cm^2, see Fig. 2, right), and on a multitouch tablet device (18×28 cm^2). The users' perception of these input devices was measured within the evaluation of the game, though the devices differed in size, resolution, and latency. Still, this evaluation will reveal whether there are utterly unsuitable devices for interacting with the game or whether the game is usable regardless of the interaction media.

Fig. 2. Cook It Right on the wall-sized multitouch display (left) and on the table (right).

4 Evaluation

The following study explores how older adults interact with serious games in ambient assisted home environments, taking the presented game "Cook It Right" as an example. To understand the factors that contribute to game performance and to acceptance (i.e., intention to use the game and later adherence) we carried out a controlled experiment with prototypic elderly users, a younger control group and different interaction devices. The voluntary participants were all in full possession of their cognitive and motor skills, and had normal or corrected-to-normal vision. As none of the participants was

[1] An in-depth presentation of the room is available online: http://vimeo.com/31951636.

living in a (technology) assisted living environment, they were introduced to the vision of ambient assisted living and the potential of a serious game for cognitive training. The investigated measures were captured using questionnaires before and after the game intervention. Log files captured all user interactions with the game. The experiment took about 45 to 60 min. for each participant.

The following research questions guided this study: First, what are the key determinants that explain acceptance of the game? Second, what are the key determinants that explain performance within the game? Third, which interaction device is most suitable to support older adults in terms of performance and acceptance?

4.1 Independent Variables

We controlled and manipulated the independent variables *age*, *gender* and *device type* for the sample. It consisted of 50 % male and 50 % female and 50 % younger and 50 % older users. *Device type* is a between- subjects variable and the participants interacted with one of three devices *tablet*, *table*, *wall* available in the AAL environment.

Level complexity: The game's complexity increases with each level. Participants started with the easiest level (*scrambled egg*) that requires at least 6 interaction steps (Fig. 3, left, illustrates the recipe tree). This level was played as a guided tutorial: The subjects learnt the interaction principles and optional help was provided by the investigator. The second recipe (*pancake*) is of medium complexity and requires at least 14 steps (see Fig. 3, center). The last recipe (*steak and roast potatoes*) has the highest complexity, though it also requires 14 steps (see Fig. 3, right). This illustrates that complexity is more than the number of elements, as the increased complexity is a result of the wider recipe tree (see [42]).

4.2 Control Variables

The control or explanatory variables cover individual factors that were measured during the study, but not specifically used for constructing the sample.

Gaming frequency: We measured the subjects' inclination towards playing games as the playing frequency across a wide set of different games and activities (from card games to outdoor games).

Technology expertise: The users' technology expertise is captured as usage frequency and perceived ease of use across different electronic devices and the self-efficacy in interacting with technology using a standardized scale by Beier [43].

Health-related behavior: Participant's health related behavior is captured by the health sub-scale of the Domain Specific Risk-Taking scale (DOSPERT [44]).

Cooking self-efficacy: To understand the relationship between domain knowledge and rating of or performance in the cooking-related game, we measured the users' perceived ease of cooking, cooking frequency and cooking self-efficacy. These cooking scales are congruent with the technology scales.

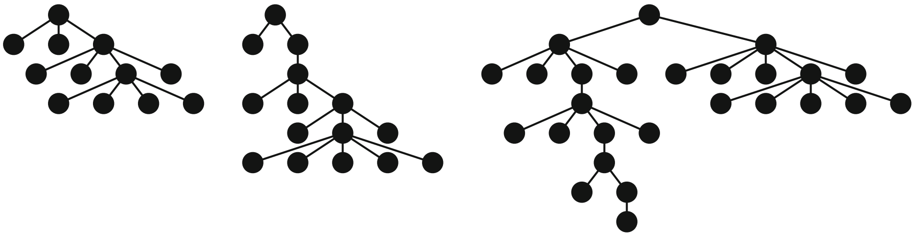

Fig. 3. Illustrations of the recipe trees for simple (left), medium (center), and hard (right) levels.

4.3 Dependent Variables

The dependent variables in this experiment fall into three categories: First, the variables capturing the acceptance of the used input devices. Second, variables that measure the overall acceptance of the game. Third, variable that measures the performance and completion of each level.

To understand which input devices are suited best for interacting with this serious game, the participants furthermore rated their interaction devices with regard to (perceived) *suitability*, *input precision*, and *learnability*.

As dependent variables, the seven dimensions from the UTAUT2 [45] model were measured: *Performance Expectancy*, *Effort Expectancy*, *Facilitating Conditions*, *Habit*, *Social Influence*, *Price Value*, and *Hedonic* were measured through 3 items each on 6 point Likert scales (see below). *Behavioral Intention* captures the users' intention to use the technology in the future was also assessed by 3 items. According to UTAUT2 and related models, there is a strong relationship between *Behavioral intention* and the later *use* of the technology (that cannot be captured at this development stage).

Furthermore, *efficiency* (time on task for each level in *s*) and *effectivity* (number of executed steps, and completed/not completed) is measured for each level.

We used a similar design to evaluate an exercise game within the AAL lab. A more verbose description of the lab, the measured variables and details about the reliability measures of the scales can be found in [27].

4.4 Statistical Methods

All subjective measures were measured on 6-point Likert scales and then analyzed with statistical methods, such as Person's χ^2, uni- and multivariate analyses of variance (ANOVA/MANOVA) and multiple linear regression analysis. Type I error rate (significance level) is set to $\alpha = .05$. Spearman's ρ is used for reporting bivariate correlations, Pillai's V is reported for the omnibus effect of the MANOVAs. For multiple linear regressions the step-wise method was used and models with high variance inflation (VIF $\gg$ 1) were excluded. Parametrical tests are robust against small violations of assumptions. Hence, non-parametrical tests were used to validate the findings, but results from the parametrical tests are reported. Further, a Kolmogorov-Smirnov test confirmed that both key variables *Performance* and *Behavioral Intention* are normally distributed ($Z = .693, p > .723$; $Z = .837, p > .485$) and that using parametrical methods is admissible.

4.5 Description of the Sample

64 people have participated in the study (34 male, 30 female) and the age ranged from 16 to 84 years (avg. 41.6 years, SD 18.4). To investigate age-related effects using factorial methods, the sample was split into a *young* (M = 25.6, SD = 4.3) and *old* (M = 56.7, SD = 12.9) group at the median age. These groups were not associated with gender ($\chi^2(1, N = 64) = .071, p = .790 > .05$, ns.).

Age has a strong negative influence on gaming frequency ($\rho(64-2) = -.731$, $p < .01$, sig.) and older participants play less than younger participants. Furthermore, older participants report a healthier lifestyle than younger participants ($\rho(64-2) = -.323, p < .01$). As in previous studies, age has strong negative influence on perceived ease of using technology, usage frequency and self-efficacy in interacting with technology ($\rho(64-2) = -.399, p < .01$). Perceived ease of cooking, cooking frequency and cooking self-efficacy is independent of age ($\rho(64-2) = .108, p = .394 > .05$).

Gender is only marginally related to gaming frequency ($\rho\,(64-2) = -.234$, $p = .063 > .05$) with men being more inclined to games than women. Within this sample, gender is unrelated to the attitude towards health ($\rho(64-2) = .079$, $p = .535 > .05$). Also in line with previous findings, gender influences a person's self-efficacy in interacting with technology ($\rho(64-2) = -.376, p < .01$). Men have higher self-efficacy in interacting with technology than women. Interestingly, gender influences perceived ease of cooking, cooking frequency and cooking self-efficacy ($\rho(64-2) = .293, p = .019 < .05$) with women being more inclined to cooking than men.

Surprisingly, participant's gaming frequency and health related behavior are connected ($\rho(63-2) = .281, p = .026 < .05$), with gamers being less anxious about their health than non-gamers.

5 Results

The results section is structured as follows: First, the factors contributing to performance within the game are presented. Second, the determinants for acceptance and presumed later use of the serious game are shown. Finally, the comparison of the three different input devices is presented.

5.1 Determinants for Performance

Only one participant had difficulties solving the given tasks. All others completed all tasks perfectly and with or near the minimum number of required steps in each level. Hence, the following section only addresses the individual differences regarding the time for completing each level.

The time for completing a level increases significantly with the level's difficulty and the player's age $\left(V = .300, F_{2,37} = 7.915, \eta^2 = .300\right)$.[2] As illustrated in Fig. 4, older players are on average 27 %–33 % slower than younger players. Corresponding, a multiple linear regression with performance as dependent variable and independent and explanatory variables as independent variables reveals that *age* is the strongest predictor for performance ($r^2 = .278$). The second contributing factor *gaming frequency* explains additional $\delta r^2 = .100$ of variance in performance ($r^2 = .366$) and people who play games often are also faster in the game. The model's parameters are given in Table 1a. Surprisingly, neither gender, nor attitude towards health, nor technical self-efficacy, nor cooking self-efficacy significantly influences performance within this sample, if controlled for age and gaming frequency.

Table 1. Regression tables for *Performance* ($r^2 = .366$) (left) and *Usage Intention* based on UTAUT2 ($r^2 = .633$) (right).

Model	B	SE B	β	T
(constant)	.000	.000	–	8.614
Age	.000	.000	-.886	-5.003
Gaming freq.	.000	.000	-.466	-2.634

Model	B	SE B	β	T
(constant)	-.437	.360	–	-1.214
Hedonic	.635	.091	.594	6.992
Habit	.464	.114	.345	4.061

5.2 Determinants for Acceptance

Regarding the personality factors none of the dependent and control variables has an influence on behavioral intention. Specifically, neither *gender*, previous *gaming frequency*, *technical self-efficacy*, *cooking self-efficacy*, nor the *attitudes towards health* influences the *intention to use* the game and the relationship between *age* and *intention* is above the level of significance ($\rho(62 - 2) = .229$, $p = .069 > .05$, n.s.).

Five of the seven dimensions from the UTAUT2 model are strongly related to the intention to use the game (*Performance Expectancy*, *Habit*, *Social Influence*, *Price Value*, and *Hedonic*). Only the two dimensions *Effort Expectancy* ($\rho(62 - 2) = -.113$, $p = .373 > .05$, n.s.) and *Facilitating Conditions* ($\rho(62 - 2) = .052$, $p = .686 > .05$, n.s.) are not related to usage intention.

To disentangle the interrelationship between the variables from the UTAUT2 model and the personality factors a multiple linear regression analysis was calculated. Intention to use is used as dependent variable and the independent, control and UTAUT2's model variables, as well as average performance are used as independent variables. The regression reveals a significant model with the two explaining factors *hedonic* and *habit* that explains $r^2_{adj} = .633$ of the variance. Table 1 (right) shows the regression model.

[2] Due to technical difficulties with the performance log files the evaluation of game performance is based on 45 of the total 64 cases (70 %).

Table 2. Relation of independent, explanatory, UTAUT2 variables, and Behavioral Intention (BI) (n = 64), Note:' p < .1, * p < .05, ** p < .01. Gender dummy coded (1 = male, 2 = female).

	PERF	PE	EE	FC	HA	SO	PV	HE	BI
Performance Expectancy (PE)		–	-.434**		.537**	.487**	.628**	.487**	.499**
Effort Expectancy (EE)	.249+		–	.490**			-.264*		
Facilitating Conditions (FC)				–					
Habit (HA)					–	.544**	.476**	.453**	.578**
Social Influence (SO)						–	.430**	.611**	.612**
Price Value (PV)							–	.318*	.413**
Hedonic (HE)								–	.718**
Age	-.675**	.407**	-.269*			.222'	.334**	.477**	.229'
Gender			-.289*			.358**			
Health-related behavior	.367*								
Gaming Frequency	.373*	-.335**	.304*			-.250*	-.350*	-.317*	
Cooking Self-efficacy									
Technical self-efficacy	.495**	-.342**	.290*			-.257*		-.283	

The interrelationships between independent and explanatory variables and the dimensions from the UTAUT2 model are given in Table 2.

5.3 Device

Each participant interacted with one of three devices available in the AAL environment (tablet, table, wall) and none of the participants had severe difficulties interacting with his or her device.

The general *task suitability* was rated high for all investigated input devices ($M_{all} = 4.1 \pm 1.2$, $M_{tablet} = 4.4 \pm 1.5$, $M_{table} = 4.5 \pm 0.7$, $M_{wall} = 3.5 \pm 1.2$). Although the ratings differ significantly across the three devices $\left(F_{2,61} = 4.738, p = .012 < .05\right)$, a post hoc Tukey-HSD test shows that the difference is only significant between the ratings of the wall-sized display and the table ($p = .015 < .05$). Neither the ratings of the wall sized-display and the tablet ($p = .061 > .05$), nor the ratings between the tablet and the table ($p = .926 > .05$) differ significantly.

Contrary, the perceived *input precision* was rated as less good ($M_{all} = 3.2, \pm = 1.8$) and only slightly above the scale mean (2.5). Yet, no sig. differences were found between the three devices $\left(F_{2,60} = 2.079, p = .134 > .05\right)$.

The perceived *learnability* of the three input devices was rated high ($M_{all} = 4.4, \pm = 0.8$) and did not differ across the three devices $\left(F_{2,61} = 1.512, p = .229 > .05\right)$. Figure 5 illustrates the findings.

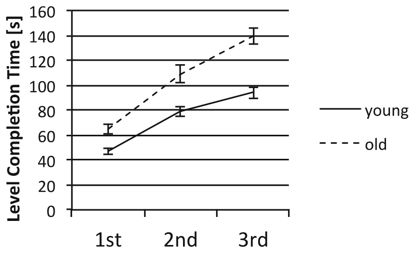

Fig. 4. Performance.

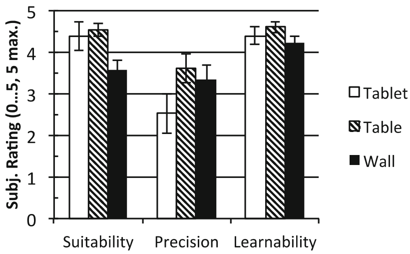

Fig. 5. Device ratings.

6 Discussion

We designed, implemented, and evaluated a prototypic serious game for ambient assisted living environments. The game aims at training the cognitive abilities (specifically remembering and planning competencies) of the residents and runs on several of the interaction surfaces available in the prototypic living environment. The study with older adults and a younger control group reveals findings in line with our expectations and some surprising aspects.

6.1 Evaluation of the Game

First, the study showed that every but one participant completed all asks of the user study. Hence, the participants were able to read, remember, and replicate the three given recipes on one of the three interaction surfaces. Most of our prototypic users were acquainted with tablet devices, but none of the older participants had experiences with the tabletop device or the wall-sized device. Still, they had no difficulties to learn and use this touch-based technology successfully. Overall, the study showed that serious games for healthcare in ambient assisted living environments were usable by older and younger players and that a successful integration is possible. Furthermore, some elderly participants stated after the experiment that they enjoyed the seamless integration of technology in the room and that the playful application would encourage them to perform training activities regularly, while they refrain from learning to interact with current notebooks or tablets due to their high complexity (see also [28]).

Second, though this study revealed differences in the perception of the three utterly different interaction surfaces (wall, table, tablet), there is no clear "winner". Within this study, the table has received the highest overall rating, closely followed by the two other interaction surfaces. Still, none of the devices was rated unsuitable and the participant's had little difficulties completing their tasks regardless of the device.

Third, according to our expectations (and the companion study presented in [27]), *age* is the strongest predictor for game *performance* and performance decreases with age. The second strongest predictor is gaming frequency, meaning that people who are inclined to games and play games frequently were faster in *Cook it Right* than people who are less inclined towards games. Contrary to the companion study (see Sec. 2.4), neither gender, nor need for achievement influences the performance. Also, domain expertise (measured as cooking frequency, ease of cooking and cooking self-efficacy) does not influence performance. Surprisingly, self-efficacy in interacting with technology is unrelated to game performance if controlled for age. This contrasts innumerable studies in which people with lower technical self-efficacy suffered from lower performance (efficiency) and lower completion rates (effectivity). We speculate that the triad of a game-based environment, touch based interaction surfaces, and the hand-drawn appearance of *Cook it Right* lowers the perceived and actual barriers to a successful use and adoption of ICT-based medical technology. Besides completion time the number of interaction steps was also considered, but almost all participants completed the levels with the minimum number of steps. Hence, they did not use the trial-and-error method and they were not rapidly testing all possible combinations. We think that this is caused by the rather strong visual cues the game offers, e.g., it is easy to see when a steak is placed in a pan and none of the participants tried to add steaks multiple times. A follow up study with more difficult levels will need to investigate the influence on user factors on the number of interaction steps and their influence on the usage intention. We assume that if people "feel lost" in more complex recipe trees the number of non-functional interaction steps will increase and the usage intention will derogate. Similar findings were already observed for interacting with menu trees on small screen devices [46] and the transferability of these findings must be investigated in the context of games and AAL.

6.2 Guidelines for the Successful Introduction of Serious Games for Healthcare

Intention to use the game is mostly explained by the factors within the UTAUT2 model and not by personality factors. Only *age* mildly influences the intention to use the game, with older players being more inclined towards the game. The nature of this effect is still unidentified and requires further investigation. A possible explanation for the higher usage intention of older participants may be that they can better relate to the concept of cognitive trainings. Alternatively, younger participants may have a lower usage intention as they are spoiled by current game titles. Strikingly, the evaluation of the game is independent of the achieved performance. Hence, even people who do not perform well due to cognitive or technical difficulties enjoyed the game. Regarding the UTAUT2 model's variables the study showed that neither *effort expectancy*, nor *facilitating conditions* influence the intention to use the game. Hence, the participants believe that the presented game-based technology is easy to learn and that they do not need to rely on support by others to successfully use the game. All other constructs from UTAUT2 have a strong positive influence on the usage intention. Designers and developers of games for healthcare, as well as medical professionals accompanying the introduction of these games, should closely pay attention to these constructs, as they are crucial for a successful introduction of serious games for healthcare in ambient assisted living environments.

Guidelines for an effective introduction of serious games for healthcare can be formulated based on the determinants of usage intention. A high hedonic value is the strongest lever for later use. Hence, designers must carefully craft games that are enjoyable by the target audience. Furthermore, it is advisable that potential players are included in the design process from the beginning, to ensure a fun game play and an interesting game scenario. The second-strongest aspect is a persons' believe of making playing the game a habit. Thus, a successful integration of serious games for healthcare depends on accompanying measures that strengthen this feeling. Bandura's self-efficacy theory [47] suggests role models that successfully use the games in their daily life or social support by friends and family members. The latter also relates to the social influence dimension from UTAUT2, which also has a positive influence on the usage intention. Although a reasonable price-value tradeoff is of lower priority within this study, the financial investments still have an influence on the acceptance. As health insurance companies will profit from a widespread and frequent use of healthcare games, they should invest in these to support their diffusion.

7 Limitations and Outlook

The presented results reflect the users' short-term evaluation of the game. Therefore, a long-term evaluation must address the interrelationship between behavioral intention and actual behavior (i.e., adherence to the game) over time. Also, this evaluation relates to the design of the game and may change with games addressing a different domain or different interaction styles. We think, however, that the findings presented here are transferable to serious games in general, as we have similar results on an exercise game [27].

The data presented here was aggregated from separate studies for each input device and the evaluation of these is only briefly discussed here and the evaluation was carried out in context of the game and the environment. Hence, the findings might be intermingled with influences therefrom. A follow-up study should more closely address the barriers and benefits of the different input devices. A within-subject experiment focusing solely on the user's perception, performance, and effectivity with the three devices should reveal which device is suited best for delivering the game or whether a bouquet of input devices can and should be provided in AAL environments.

It is a necessity to understand the user's wishes and demands on serious games for healthcare. Not only regarding the objectives and themes of the games, but also regarding the possible interaction interfaces. The present study presents a glance on these questions; nevertheless further studies will need to explore the design space of input devices in AAL environments and its relationship with serious games for healthcare.

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