Game-based design for eHealth in practice

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Abstract

Background: Games are increasingly used in eHealth as a strategy for user engagement. While these game-based applications receive attention in literature, there is an enormous diversity of end users and objectives targeted by eHealth. Identifying game content that drives and sustains engagement is therefore challenging. Future developments would benefit from more openness on the game design process and motivational strategies applied.

Objective: Our objective was to provide insight in our approach in the development of game-based eHealth in practice. By means of a case study, PERSSILAA, we elaborate the entire game design process and show the motivational strategies applied, to aid researchers and designers of future game-based applications. PERSSILAA is a self-management platform which aims to counter frailty by offering older adults training modules in the domains of healthy nutrition, physical and cognitive training to maintain a healthy lifestyle.

Methods: We introduce four phases in the process towards game-based eHealth: 1) end-user research, 2) conceptualisation, 3) creative design and 4) refinement.

Results: A total number of 168 participants participated in end-user research (1), resulting in an overview of their preferences for game content and a set of game design recommendations. We found that conventional games currently popular among older adults do not necessarily translate well into engaging concepts for eHealth. Recommendations include: focusing game concepts on thinking, problem solving, variation, discovery and achievement, using high quality aesthetics. Stakeholder sessions with developing partners resulted in strategies for long-term engagement (2), using indicators of user performance on the platform's training modules. These performance indicators, e.g. completed training sessions or exercises, form the basis for game progression. Results from prior phases were used in creative design (3) to create the game "Stranded!". The user plays a shipwrecked person who has to gather parts for a life raft by completing in-game objectives. Iterative prototyping (4) resulted in the final prototype of the game-based application. A total number of 35 end users participated using simulated training modules. The online game-based application was used without reported errors for a six weeks. End users scored appreciation (74/100), ease of use (73/100), expected effectivity and motivation (62/100), fun and pleasantness of using the application (75/100) and intended future use (66/100) which implicates that the application is ready for use by a larger population.

Conclusions: The study resulted in a game-based application for which the entire game design process within eHealth was transparently documented. We believe we have contributed to the transfer of knowledge on game design that supports engagement in eHealth applications. Our user evaluations indicate that results from end-user research and consequential strategies for long-term engagement led to game content that is engaging to the older adult end user.

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Original Manuscript

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Abstract

Background Games are increasingly used in eHealth as a strategy for user engagement. While these game-based applications receive attention in literature, there is an enormous diversity of end users and objectives targeted by eHealth. Identifying game content that drives and sustains engagement is therefore challenging. Future developments would benefit from more openness on the game design process and motivational strategies applied.

Objectives Our objective was to provide insight in our approach in the development of game-based eHealth in practice. By means of a case study, PERSSILAA, we elaborate the entire game design process and show the motivational strategies applied, to aid researchers and designers of future game-based applications. PERSSILAA is a self-management platform which aims to counter frailty by offering older adults training modules in the domains of healthy nutrition, physical and cognitive training to maintain a healthy lifestyle.

Methods We introduce four game-design phases in the process towards game-based eHealth: 1) end-user research, 2) conceptualization, 3) creative design and 4) refinement (i.e., prototyping and evaluations).

Results (1) A total number of 168 participants participated in end-user research resulting in an overview of their preferences for game content and a set of game design recommendations. We found that conventional games popular among older adults do not necessarily translate well into engaging concepts for eHealth. Recommendations include: focusing game concepts on thinking, problem solving, variation, discovery, and achievement, and using high quality aesthetics. (2) Stakeholder sessions with developing partners resulted in strategies for long-term engagement, using indicators of user performance on the platform's training modules. These performance indicators, e.g., completed training sessions or exercises, form the basis for game progression. (3) Results from prior phases were used in creative design to create the game "Stranded!". The user plays a shipwrecked person who must gather parts for a life raft by completing in-game objectives. (4) Iterative prototyping resulted in the final prototype of the game-based application. A total number of 35 older adults participated using simulated training modules. End users scored appreciation (74/100), ease of use (73/100), expected effectivity and motivation (62/100), fun and pleasantness of using the application (75/100) and intended future use (66/100) which implicates that the application is ready for use by a larger population.

Conclusion The study resulted in a game-based application for which the entire game design process within eHealth was transparently documented, and where the engagement strategies were based on extensive user research. Our user evaluations indicate that the strategies for long-term engagement, led to game content that was perceived as engaging to the older adult. As a next step, research is needed towards user experience and the actual engagement of the game to support self-management of older adults , followed by clinical studies towards its added value.

Keywords

Game-based, gamification, game, eHealth, telemedicine, development, design, engagement, game preferences, elderly, seniors, older adults, self-management, prototyping, evaluations, creative.

Introduction

Digital healthcare applications can contribute to improved self-management of patients and increased health literacy, alleviating the burden on healthcare professionals at the same time [1-5]. This eHealth, defined as the field in the intersection of medical informatics, public health, and

business, refers to health services and information delivered or enhanced through the Internet and related technologies [6]. However, maintaining adherence rates among users, related to better health outcomes [7], remains an issue [8,9]. Games, or elements from games (e.g., gamification, serious gaming, game-based design, and applied games), are often used as a strategy for creating motivational concepts to stimulate engagement [10-12], thereby retaining adherence of the end-user to the objectives of these eHealth applications [13,14]. Over the past few years, these gaming strategies have evolved from a novel and experimental industry practice to a more mature field of research with applications in diverse domains [15]. As such, there is an expanding body of literature on studies towards the potential and effects of such 'gamified' applications [16,17] while the broader adoption of games for eHealth is still in its infancy [18-21].

A general success formula does not exist for game-based design in eHealth, as the applications in eHealth target a diversity of specific goals and users. To develop successful gaming motivation strategies in these applications we must overcome several challenges. Firstly, strategies that contribute to the success of a game-based application remain hidden when the rationale behind design choices does not receive attention in literature. We may be able to discover suitable game design strategies from these works by for example reverse engineering or mass analysing contents of existing applications. However, when the actual game design itself happens within a black box [22,23], successful concepts or theories lose their motivational capacities once borrowed and applied outside of their original context. There is a need to open this black box and bring research findings into practice in a useful way, which can aid developers of game-based applications in the selection of suitable content, principles, or mechanisms.

A second challenge lies in creating game content that creates durable engagement to sustain motivation, as is crucial in gamified applications [24], to adhere to the health objectives. Often, developers seem to accomplish short-term user engagement through extrinsic reward systems [11] as is suggested by gamification practices from industry (for example [25]), which have dominated the field [26]. Game design should however be created for an optimal user experience in terms of aesthetics, usability and fun [12], and primarily be entertaining [27]. By gaining insight into the preferences of the user, content can be tailored [29] to satisfy their motivational needs [30] which contributes to an engaging experience. This insight is gained through assessing the unique properties of the targeted end-user and adequately addressing these through selecting game elements that are in line with these preferences, as well as carefully considering the context of use and health objectives.

The purpose of this article is to provide insight in a start-to-end design trajectory of game-based eHealth. We aim to overcome the abovementioned challenges by documenting the game design process and exploring design strategies for sustained engagement. We demonstrate this approach in a case study on an eHealth platform for the older adult, called PERSSILAA (PERsonalised ICT Supported Services for Independent Living and Active Ageing). PERSSILAA was developed to identify and counter frailty among older adults. Frailty is a condition that affects many older adults. Frail older adults are at increased risk for development of disability, dementia, and hospitalisation [32]. The condition is multifaceted and the major dimensions of the decline, which often occurs gradually and goes unnoticed for a long time [33], are physical and cognitive decline as well as malnutrition [34]. This vulnerability for decline is caused by a lifestyle that lacks stimulation on these three dimensions, a lack of sufficient mental stimulation, physical activity, or healthy nutrition. Fortunately, when the decline is identified at an early stage – so-called pre-frailty – it can be slowed down or even reversed by offering suitable training on these

three aspects [35].

Methods to detect (pre-)frailty among older adults and offer them the right training have been successful but resource-intensive, and the demand for this specialised care is increasing by an ageing population in Europe. The PERSSILAA platform aims to enable older adults to independently work on their health targets [36]. By combining eHealth and community-based service, moving away care from institutions while the older adult gains autonomy [37].

A particular challenge, in this case, was to sustain motivation of the older adult for long-term usage. The older adult is a generally underexplored target group in gaming [31]. We present the development of this game-based application from initial end-user research to the final version that is ready for use in real practice.

Methods

2.1 Game design process

The game design process consisted of four phases as part of the healthcare application design and development process of the eHealth application *(fig. 1)*. These four phases were:

1. End-user research phase: investigation of game preferences of the end user and specifications from the use context of the envisioned application
2. Conceptualisation phase: addressing system and application architecture and the conceptual development of long-term engaging game content suitable for the end-user.
3. Game design phase: performing the creative and constructive processes.
4. Refinement phase: prototyping and user evaluations

Each of these phases is discussed as if chronologically occurred, but insights gathered during subsequent phases often lead to adaptations in earlier ones. Each phase consists of several sub-steps, as shown in Figure 1.

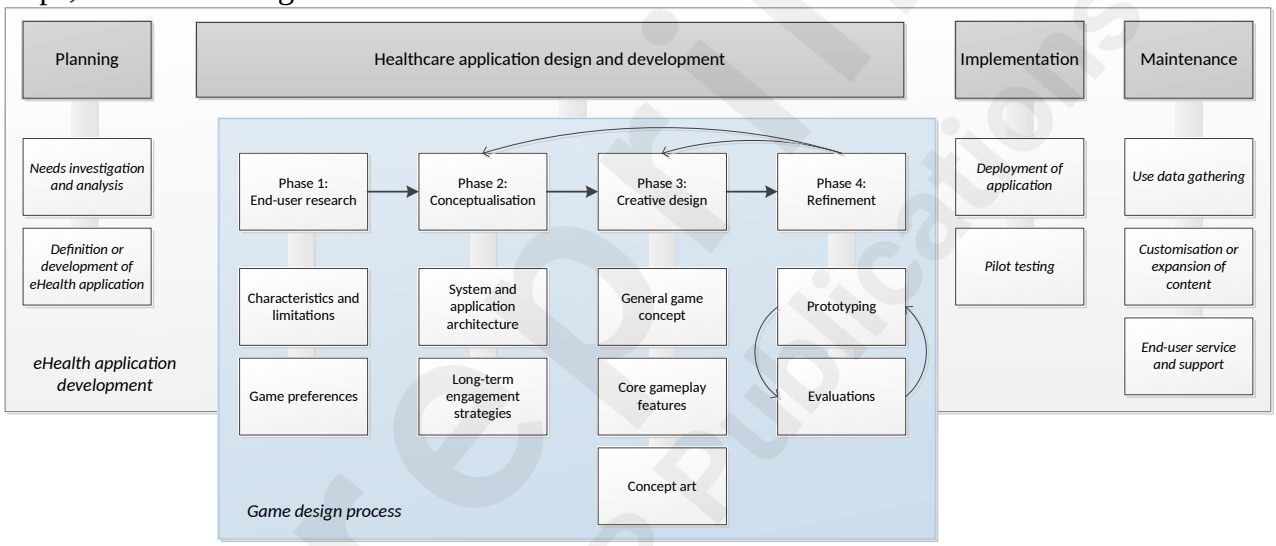

Figure 1 – Game design process within eHealth application development

For completeness, the full development cycle of the game-based eHealth application contains three more processes: planning, implementation, and maintenance *(fig. 1)*. Planning takes place prior to the healthcare application design and development. Here, the need that the envisioned eHealth application will fulfil is recognised and analysed. Then, in implementation, the rollout of the developed gamified application for use in practice occurs. If necessary, training of primary and secondary end-users (e.g., caregivers, family members) also takes place during implementation. Maintenance starts once the application is launched and stretches the total lifespan of the application. It covers service and support for the end-user, as well as back-end maintenance and keeping content up to date.

2.2 Game design process phase 1 – End-user research

2.2.1 End-user characteristics and limitations

User characteristics within the context and goals of the eHealth application were explored. This includes all aspects relevant to consider when creating the game design, such as computer literacy, experience with related technologies including games and specific usability

requirements.

In the case study, we explored the characteristics of the target group eligible for the use of the gamified PERSSILAA self-management platform.

2.2.2 Recruitment of participants

136 participants (aged 65-75) were recruited, the inclusion criterium was sufficient computer literacy to independently use mobile devices or a pc and an interest in digital games. The participants were asked to answer a demographic questionnaire which include the abovementioned characteristics. Also, an informed consent form for participation was provided and signed by the participants.

2.2.3 Game preferences

The preferences of the target user towards specific game content must be investigated to be able to design engaging gamification. In previous work, a framework to assess and classify these preferences was developed [38-40] [54]. Assessment results in a 'user profile', subsequently translated into game design recommendations.

In the case study, we researched the specific game content that satisfies the older adult user. We reverted to a previously performed study [40], Study A and performed a follow-up [54], Study B. Study A focuses on investigating the general game preferences of older adults before and after providing them with a tablet with modern games to play, which were assessed through questionnaires and a semi-structured interview. Study B investigated the game preferences of older adults in a situation related to the use context of PERSSILAA, demographics, gaming behaviour and game preferences were measured through questionnaires. Perception and appreciation of the user regarding the game content presented in the gamified application were measured using a 1-5 VAS scale and semi-structured interviews. The results create an overview of the game preferences of the older adult regarding their gaming behaviour and preferences based on their current, prior, and recent experience with (video) games. Also, we continued to elaborate on findings by assessing game preferences before and after using for several weeks a gamified eHealth application that was developed specifically for this target group. The games and the gamified application were previously unknown to the participants.

2.3 Game design process phase 2 – Conceptualisation

2.3.1 System and application architecture

As the non-gamified application development occurs in parallel, its system architecture is analysed to decide on the role and extent of the game-based design within this architecture.

In the case study, the development of the underlying, 'standard' eHealth application occurred in parallel with the four phases of the gamification design process. The system architecture was charted in close cooperation with the back-end developers of the application. Firstly, we decided on the extent of autonomy of the user to choose to use or disable (sections of the) gamified application and investigated the possibilities to implement these functionalities into both interfaces (gamified and standard). Secondly, we determined the possible variations or restrictions to the functionalities of the application in case specific (negative) health advice is given to end-users. Thirdly, milestones were identified for the inclusion of functionalities from the standard eHealth application in the gamified version at several moments in time.

2.3.2 Long-term engagement strategies

To support and sustain user engagement over a pre-determined amount of time, the components of the standard eHealth application that should be represented in the gamified version for meaningful interaction have to be identified. This is a recommended second step to the conceptualisation phase.

In the case study, we investigated how to quantify the user's performance on the underlying healthcare objectives. This performance needs to be measured as it plays a key role in strategies to sustain the engagement of the user with the application along its entire use time. The activities that enable measuring the progress of the user serve as input for the gamified application and eventually result in game content.

Developing partners in three domains of expertise (physical, cognitive, and nutritional health) have contributed to the realisation of functionalities and services of the eHealth application. To do so, we identified the actions within each of these three domains that were key to the performance of the user as they indicate their training progress. These actions, which we called 'performance indicators', had to be reflected through game content to support engagement. We quantified this progress by means of abstract 'game units' (GU). This level of abstraction allowed for the reflection of personal performance, and the possibilities of constructing a system that accommodates compensation between the progress of different users to create a fair and even gaming experience.

2.4 Game design process phase 3 – Creative design

In this phase, the identified elements are concretised into the design of a meaningful user experience, including aspects such as gameplay and storyline, utilising the knowledge gathered in phase 1. The result of this phase is the creative concept of the gamified application, often referred to as the 'high concept'.

We subdivided creative design into three key topics: 1) the general game concept, 2) core gameplay features and 3) concept art, covering the visual and auditory outline of the game. We approached the game design phase as a cyclical idea-generation process supported by creative sessions *(fig. 2).* In addition, brainstorming sessions serve to reflect on and generate new insights and ideas. Quantifying performance indicators and outlining the game's progress are addressed separately.

During this phase, the game design documentation is created [41]. This is a living document, accessible by all members of the developing team, that is continuously edited and updated. The document covers all aspects important to the development of a game, describing the vision, contents and planning stages of prototyping and implementation, as well as any outsourcing plans.

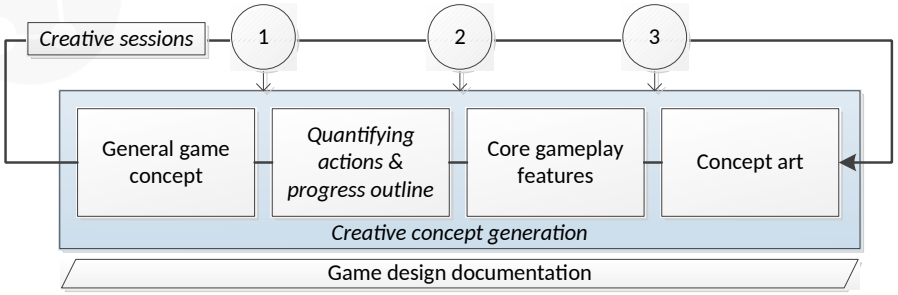

Figure 2 – Game design phase (as applied in case study)

In the case study, three larger sessions have taken place during the creative design phase to support the development of the creative concept by the game designer and to ensure optimal

integration of all stakeholder's interests. In the first session, all developing partners of the PERSSILAA project participated in the creative concept for the gamified application. In the second session, ideation regarding feedback- and reward systems, core gameplay elements such as discovery, collecting items and level progression, as well as ideas for the central theme. In the third session, validation regarding the suitability of specific game elements was questioned based on insights of participants within their own expertise and experience with the target group, research, and related technologies.

2.5 Game design phase 4 – Refinement

The last phase of the gamification design process covers the development of the prototype. This occurs in several stages, aided by a series of evaluation sessions. In *figure 3* we illustrate this phase, as applied in the case study, in simplified form along with its major milestones.

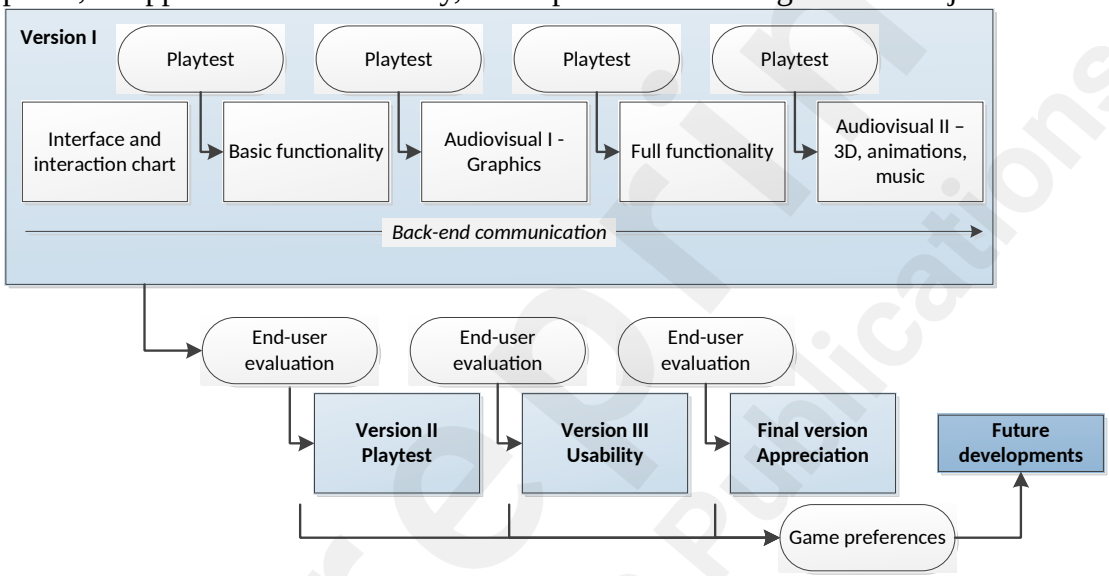

Figure 3 – Refinement phase (as applied in case study)

2.5.1 Prototyping

As the fidelity of the prototype evolves from low to high, the back end, functionality, and visual features mature until the fully functional prototype is created. In early development, refinement iterations are more rapid and substantial.

In the case study, four main versions were created as predetermined by milestones set in the conceptualisation phase. Here we explain the version I, it encompassed realisation of the game that was increasingly functional as well as graphically attractive. The developing team and researchers thoroughly tested ('playtesting') each iteration of the first prototype to evaluate game design and usability, eliminate bugs and design flaws in an early stage. This first version of the game was then used in an evaluation session with the end user.

2.5.2 Evaluations and Data analysis

Once the prototype is done some end-user evaluations need to be held. The goal of these sessions is to validate the current version of the system.

In the case study, three end-user evaluation sessions took place. All sessions delivered the following input for the succeeding version of the prototype: 1) information on the end user regarding demographics, current gaming behaviour and past experience with games and devices, 2) perception and appreciation of the game content that is present in the game and 3)

information on technology acceptance, perceived motivation, and usability. The data on game preferences was gathered to follow-up our research as presented in phase 1, in order to refine and expand the user profile of the older adult. The domains discord, dedication, novelty, social, intensity, and threat apply to this game concept and are used to describe the preferences of the user for specific game content on a linear scale.

Session 1

The first sessions focused on playtesting the gamified application with the end user. The aim was to gather feedback on the game concept, playability, appreciation of the diverse game mechanics and the expected added value of the use of the game over the use of the standard application.

Participants were recruited by Roessingh Research and Development (RRD, Enschede, the Netherlands) for inclusion in PERSSILAA and informed in an information meeting. Participants were instructed on the use of both versions of the application. An exclusion criterion applied in case of health issues limiting the use of the original application's training modules. This criterion was automatically fulfilled, as participants of the standard application were previously assessed and classified as pre-frail.

Participants used the application, basic or gamified, in their home environments. Participants were asked to log their experience with the game and to keep track of any issues that might occur. For the purpose of troubleshooting and tracking game use, log data was gathered. After a use time of 6 weeks, participants were asked to fill in an online questionnaire on their experiences. An option was included to elaborate the choice to not use the game as well.

Questionnaire, including demographics and information on gaming behaviour and experience with devices and games were gathered. The questionnaire included questions on the theme of the game, the gameplay, the graphical style, and the used game mechanics such as the game progress. Furthermore, questions were asked on the clarity and use experience of the gamified interface compared to the basic application. These aspects were measured in 34 items rated with a 5-point Likert scale. Game preference (perception and appreciation) was measured by means of two times 17 statements on content present in the game.

Session 2

In the second session we evaluated the game concept, the expected use and motivation by the game on the long term. We measured the perception and appreciation of the presented game content by the user. This session focused on improving the usability of the game by means of video recordings and the 'thinking aloud' method.

Participants (aged 65-75 years) were recruited, this was done by means of an information letter, spread by Twentse Zorgacademie (TZA, testing and training centre for care technology,), and the test location was set at TZA Living Lab, Enschede. Participants were excluded from the study when they had no experience with using a pc, or when they were not interested in the use of the technology used in PERSSILAA. As the (physical) exercises from the PERSSILAA application were not part of the study, a lesser physical condition of the participant was not considered an exclusion criterion.

Participants received an introductory presentation by the researcher, informing them on the use and goals of the PERSSILAA application and game, as well as on the study set-up and aims of

the research. People participated in pairs and participants were invited to access the game and to perform specific tasks or actions (divided over sets of five sessions to avoid knowledge saturation [42]), while speaking their minds and discussing with each other. The underlying exercises as offered by the PERSSILAA application were simulated, to enable a walkthrough of the entire game in approximately an hour. Using screen capturing software, actions and speech of the participants was recorded. After the session, participants were invited to fill in a questionnaire in a second room on (separate) pc's.
The questionnaire assessed demographics and information on current and past gaming behaviour and experience with the use of devices of the end user. We measured the opinion of the participant using the UTAUT questionnaire [43] for performance and effort expectancy (76 items rated on a 7-point VAS scale). Formulation of the questions was adapted from the original to the technology used in this particular situation. The expected use of the game was measured by presenting a hypothetical use situation. In addition to the video and audio recordings, the questionnaire assessed usability of the game in general and of specific aspects of the game. Scores on these aspects (overall appreciation, ease of use, performance and effort expectancy including expected effectivity versus motivation from the game, fun factor and intended future use) were calculated. The preferences for game content of the end user were measured by means of two times 51 propositions on the content present in the game (5-point Likert scales).

Session 3
The third and last evaluation session used the same methods of *session 2*. However, the game was presented to the user in a stand-alone version that could be used from the participant's home situation and was not played in couples but individually. No audio or video recordings were made. The questionnaire was filled in through an online form.

Results

3.1 Phase 1 – End-user research

3.1.1 Characteristics and limitations

The target group is the older adult, aged 65-75, with sufficient computer literacy to independently use mobile devices or a pc and an interest in digital games. Of the older adults questioned *(n = 136, mean age 69)*, 75% indicates to play games of which 75% plays at least once a week or even daily (more than 40% in total). Approximately 75% of frequent players indicates to play digital games (or 42% of all participants), next to board games or other conventional games. Computer and laptop (76%) and smart devices (60%) are the most popular media for playing. Two thirds of the total number of participants (including solely board and/or card game players) choose playing together (cooperative or competitive) above playing alone. Only few participants (n = 12) indicate that they play online social games, of which Wordfeud is mostly mentioned, or are interested in doing so in the near future. The older adult prefers to play games at home rather than elsewhere or on the go (90%).
Participants' favourite digital games *(fig. 4)* where thematically categorised into card games (e.g., Solitaire, FreeCell, Spider), word games (Wordfeud, Ruzzle, crosswords), digital versions of other conventional games (mahjong, chess, cryptograms, quizzes, bingo) and modern (online) games (candy crush, bubble shooter, search and find games). Interest in more modern games is relatively small, 13% of all answers, but present. Participants play digital versions of conventional games, of which relevant examples are Scrabble, Rummikub, a diversity of card

games and puzzle games are mentioned most often. Of all participants, 74% indicated to enjoy trying out games they do not know. In interviews, many participants (18%) find modern games suitable only for younger generations or their grandchildren, but not for them.

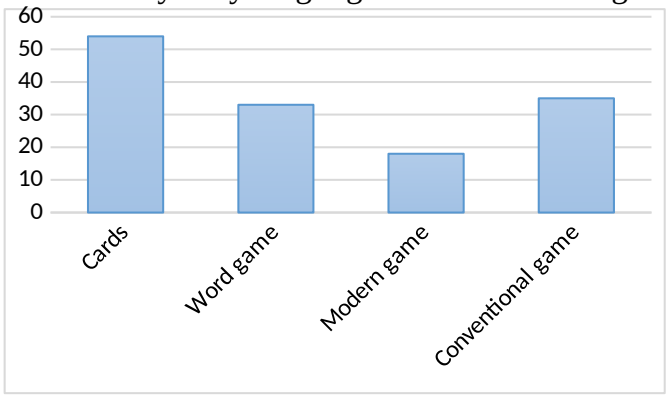

Figure 4 – Participants' current favourite games

3.1.2 Game preferences

The preferences of the older adult after playing new games or using a gamified application through questionnaires were assessed. Results of *Study 1* were presented earlier in De Vette et al., 2018b. In *Study 2*, the scores on perception and appreciation of game content were mapped onto the classification, resulting in a user profile *(fig. 5)*. The scores for the user's perception on the game content are shown in coloured, taller bars. This is the 'game profile', from the viewpoint of the older adult. The shorter, hatched bars indicate the user's appreciation of this game content. Each domain is described by two extremes, for example Intensity is described by content that ranges from slow-paced to exciting.

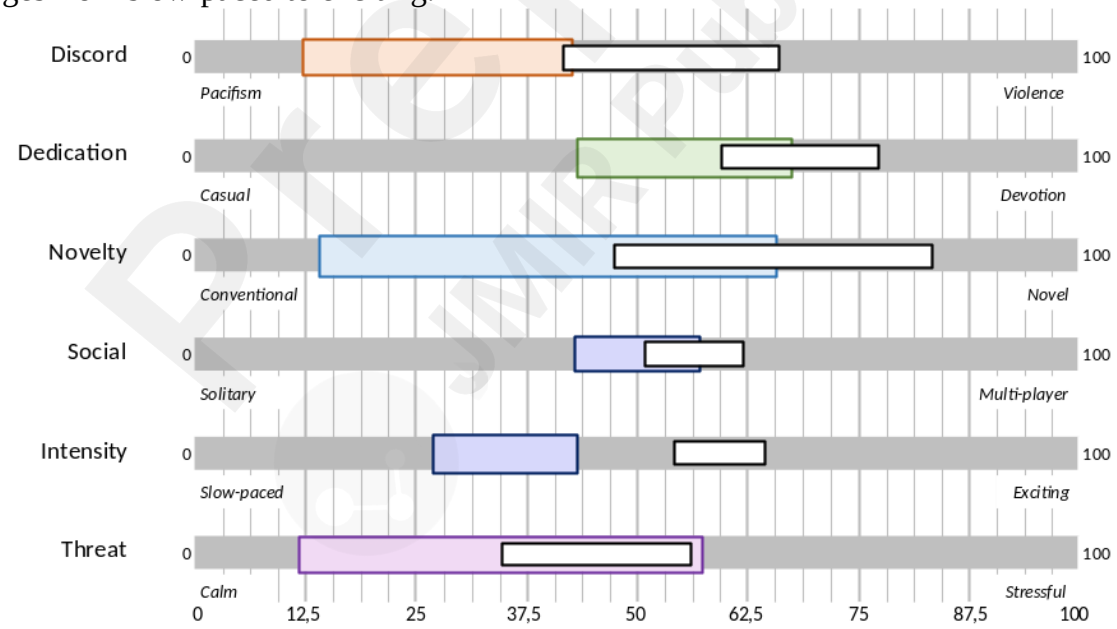

Figure 5 – User profile (perception: taller solid bars, appreciation: shorter hatched bars)

The profile illustrates the following findings. From the overlap in scores of the content of the game according to participants ('perception') and the preferred game content for a satisfying gaming experience ('appreciation'), we notice that for several participants, the game is insufficiently competitive and not demanding enough devotion. This includes challenge, effort needed to play, and learning involved. The game was considered conventional to moderately novel, including variation and aesthetics, which may not have been sufficient to engage the user.

Participants rated the social component present in the game as neutral, as both solo and multi-player options were integrated, while slightly preferring a multi-player over a solitary game. The game was not sufficiently exciting for the participant, intensity of the game was rated below preferred. The contents of the game on the domain of threat were appreciated as they were, from which we conclude that the game was not too stressful or frustrating. As discord (violence) was no apparent game feature, the score on this domain remains inconclusive at this point for use in PERSSILAA.

The additional interviews (for which we refer to the original article) gives deeper insight in the abovementioned scores on the classification. Firstly, most strikingly, participants were open to modern games and preferred less conventional game content than indicated in the earlier questionnaires. One of the games from *study 1*, Monument Valley, was particularly appreciated and played for many hours, even by those who were sceptical about (modern) video games on beforehand. Participants indicated that playing had changed their attitude towards modern video games. Moreover, in *study 2*, the game concept of the eHealth application was not appreciated at all. The game was considered not novel enough, and the conventional game concept of crosswords was not found attractive. The game did not have enough variation to maintain engagement. Participants indicated the game was too similar to the games they already knew, and the gamified application therefore did not fulfil a need.

In the off-the-shelf games and the gamified application, problem solving, intellect and thinking were found particularly motivating. The puzzle and brain training aspect of the gamified application was appreciated by most users, despite being redundant among their current gaming behaviour. Aesthetics in the game, such as good graphics and attractive artwork, were appreciated. Other motivating game characteristics related to novelty are variation, curiosity, and discovery. Participants indicated that they thought a larger selection of games would contribute to their motivation to use the gamified application.

While the older adult has an interest in social gameplay in conventional games (board games, cards), they indicated that digital games are mostly enjoyed alone. In the interviews from *study 1* and *study 2*, after the use of games or a gamified application, participants indicated that they found it enjoyable to withdraw and relax with a videogame on their own. The participants indicate that they are competitive, but this aspect is not looked for in social contact through games. In the gamified application, two social playing modes were included (competitive and cooperative), but neither option were used by the participants. Participants indicated that they did not feel the need to share gameplay, the progression in the game or their activity behaviour with other people.

We observed that the older adult has a low tolerance for frustration and negativism. Game content that creates feelings of unfairness or lack of control should be avoided. Offering additional hints, cheats or help may reduce feelings of frustration or incompetence according to the user. Participants indicated to feel underestimated by presenting game content that is superficial and easy. A childish or silly theme would however not be appreciated either. Participants indicated that a fast-paced gameplay, demanding a too high level of physical agility or reaction speed, was disliked in general. All participants indicated their strong aversion to violence.

Participants enjoyed being challenged or to challenge themselves, achieve goals, progression, and development of skills. Participants made use of statistics in the gamified application to challenge and improve themselves. Clear goals and trackable progression were mentioned as contributing to a positive experience in both studies. In the gamified application, the link

between real world activity and gameplay was not always clear, which was found demotivating. Trial-and-error in general is not an approach most older adults wish to take in games. Participants indicated that it is important that games can be paused and continued at any point, and that controls that are simple and intuitive and a goal that is clear at all times contribute to a positive experience.

3.1.3 Recommendations for engaging game content

From the abovementioned results, we deduced a set of guidelines for game design for the older adult. We aim to create a game that include the following characteristics:

- Design for moderate to high Novelty
    - Novel game concept, offering variation, renewable content, enabling exploration and triggering curiosity.
    - Attractive aesthetics and artwork, storyline, graphics
    - Focused on problem solving, logical reasoning, thinking and puzzle.
    - Provide clear rules and objectives.
- Design for moderate to high Dedication
    - Create challenging gameplay, enabling achievement, learning and mastery.
    - Offer content for devoted gameplay, such as challenges and objectives with increasing difficulty.
    - High dedication should not be compulsory to play the game at all times; add free, casual gameplay elements and low difficulty levels as well for balance.
- Design for low Discord and Threat
    - Neutral content, relaxed and cheerful atmosphere, not violent or overly friendly or cute
    - Avoiding content that triggers negative emotions such as stress, tension, a disturbing setting, frustration, anxiety, and unfairness.
    - Remove any possibility to fail, avoid negative feedback.
- Design for moderate Intensity
    - Suitable game intensity is moderately paced, avoiding exerting game elements.
    - Demanding focus of the user to complete objectives should be moderate or alternating, for example multi-tasking at high speed should be avoided.
- Design for low Social
    - As our results did not strongly indicate the added value of a social game component, the initial version of PERSSILAA will be focused on the solo player.

While we consider the available usability requirements for (game) interface design for the older adult [44-48], we regard the following game-related usability specifications:

- Goals must always be clear and progress trackable, as well as the link with those of the underlying healthcare application.
- Complex movements and controls should be avoided, game controls should be basic and intuitive.
- Completing game objectives may never relate solely on the agility of the player.
- The game should be accessible, simple game mechanisms are preferable over more complex ones.

3.2 Phase 2 – Conceptualisation

3.2.1 System and application architecture

The result of the eHealth application development is the PERSSILAA platform. The online self-management platform offers a monitoring and training program that supports both acquiring and maintaining a healthy lifestyle. This web-based service is particularly intended for people in a so-called pre-frail state, who show first signs of decline but are not yet in need of professional care, however, is accessible to several users: the older adult or patient, the caregiver, and the healthcare professional. People with proper levels of functioning are however also encouraged to use the service, as training can prevent or delay becoming vulnerable to age-related health decline.

The functionalities of the platform for the older adult are visualised in *fig. 6.* Firstly, the user logs in and is given the autonomy to always choose between the 'standard' and 'game-based' version of the platform. From within the game, the personalised (non-gamified) platform interface, or "start screen" can be recalled. The collection of data that occurs through the screening process module, via questionnaires, and the network of sensing devices forming the monitoring module, such as a step counter and digital scale, is out of scope for this article. The functionality of the game-based version is limited to the training modules and a representation of selected monitoring data.

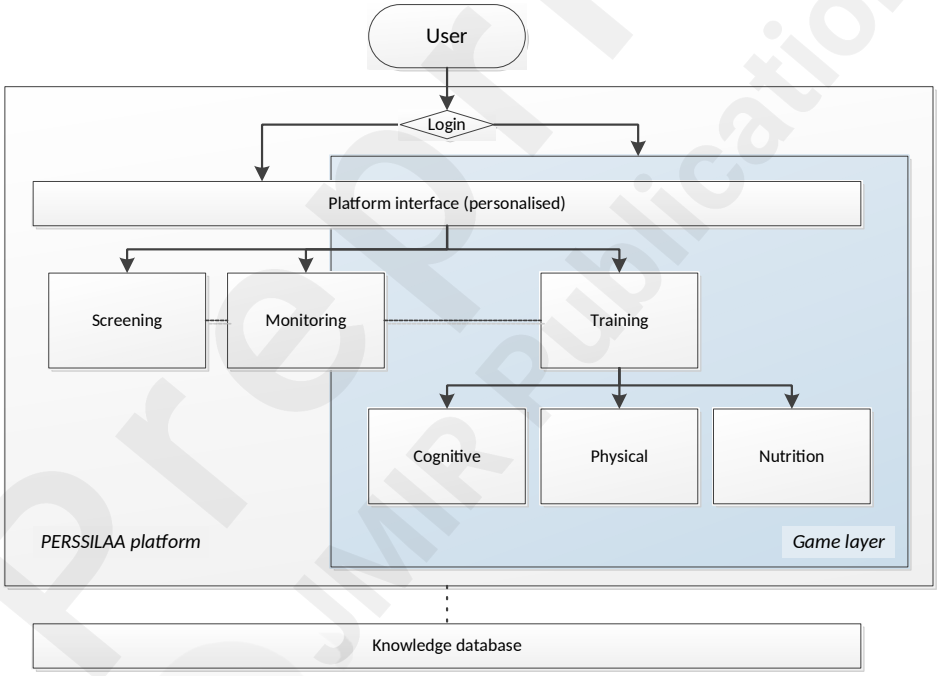

Figure 6 – The PERSSILAA system for the older adult end user. Consist in three functionalities; data-gathering questionnaires (screening), data on interaction with monitoring devices (monitoring) and training modules (training), contains physical, cognitive, and nutritional well-being.

We define four versions with increasing added functionality of the standard version into the game-based version:

1 Prototype, due at the end of refinement phase (phase 4 of gamified design process). Functionalities from the original application to include the development of the prototype: training modules, and basic monitoring.

2 First follow-up, due at the end of the implementation phase. Functionalities are those of the full platform: training, monitoring, and screening.

3 Second follow-up, due in the maintenance phase. Planned functionalities for the eHealth application that should be part of the gamified version in the future

(wearables, smart devices, digitising of the intake process). Extension of game design such as an interactive social platform, extension of already implemented functions.

4 Future versions: opportunities for future game design functionalities, unrelated to or derived from the underlying application.

3.3.2 Long-term engagement strategy

Interviews with developing partners resulted in 1) a list of activities for each particular healthcare domain that was identified as relevant indicators of user performance and 2) the assignment of fictive game units to the identified performance indicators. An excerpt of the performance indicators and their respective game units for the physical module is shown in *table 1*. The physical module provides exercising for strength, endurance, and mobility, using diverse monitoring and feedback methods on daily activity patterns.

Warming up (max. +6 GU)	4 exercises	Commencing	+1 GU
		Per finished exercise	+1 GU
Training session (max. +11 GU)	9 exercises	Per finished exercise	+1 GU
		Finishing training *(limit: 5 skipped exercises)*	+2 GU
Cooling down (max. +6 GU)	4 exercises	Commencing	+1 GU
		Per finished exercise	+1 GU
		Finishing	+1 GU
Full session			+5 GU
Answering questions			+1 GU
Regularity of training	e.g., 3x weekly		+5 GU * (1,05/week)

Table 1 – Performance indicators of physical training

The interviews resulted in notes of caution regarding possible misuse. Encouraging practice while experiencing pain must always be avoided. Skipping exercises or terminating the training must not be discouraged, and a limit of skipped exercises to complete a session may be set. Stimulating the user to practice exercises that are below their current performance level, to generate quick rewards in the game, should be avoided. Cheating the system just to gain access to new game content will be prevented as much as possible but cannot be avoided in each case.

3.3 Phase 3 – Game design

3.3.1 General game concept

The general game concept is interactive, scalable, and expandable. To the user, this gaming environment is an alternative interface that, if desired, fully replaces the original application. The gaming environment is scalable in terms of adaptability to fit the user-specific needs for access and restrictions to underlying platform functionalities. It is built for expansion with new game content to extend the time that the game is interesting to play, in such a way that changes to the original platform do not impair the functionality of the game even during use by the end user.

Following the results of Phase 1, various gaming concepts were explored. A theme was created that allows sufficient variation and exploration for the user. This gives clear rules and boundaries and can be combined with an aspect of logical reasoning and puzzle. The chosen concept is a map-based and story-driven game, to stimulate intrinsic motivation driven by curiosity and achievement. Ideas that emerged from the sessions were mini games on different map locations, including activities related to the themes of the modules, and a showcase of trophy items to gather over time.

3.3.2 Quantifying performance

From the general game concept, a suitable representation in the game of the performance of the user on the underlying training modules was created. Figure 7 shows one of the brainstorming notes. The representation of performance, through the game units, must receive a suitable, unobtrusive antagonist in the game environment.

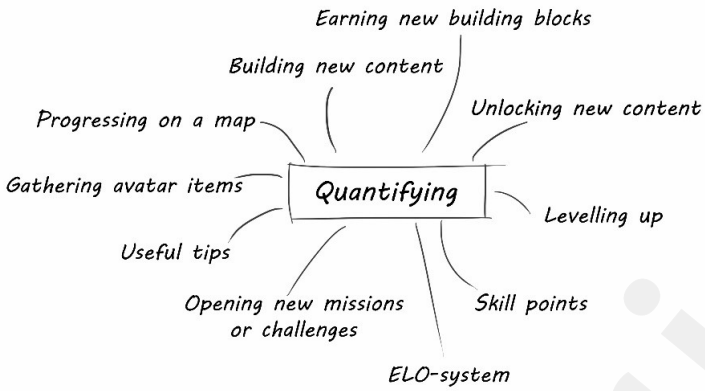

Figure 7 – Brainstorming notes from the sessions on possible solutions for the representation of performance.

The storyline in the game is the main mechanism to provide feedback and motivation on the activities on the training modules. It was planned to integrate game content for a total playing time span of 12 weeks, as this reflects an optimal use time of the original application's training and monitoring goals. Through user performance, the environment evolves and new areas to explore unlock. These areas contain gameful activities (e.g., mini games) that can be played freely, which is again rewarded with a part of the storyline of the game.

3.3.3 Core gameplay features

The game was titled Stranded! (Translated from Dutch 'Aangespoeld!'). The high-level narrative brings the player to an adventurer in late Victorian times who is shipwrecked on an unknown island in a storm. The parts of the boat that have been scattered all over the island have to be retrieved to build a new boat to get home before the volcano erupts. Every next level is opened after passing a personalised threshold of performance on the platform defined by game units. From completing each level, which will have a puzzle character, a boat part can be gained. Eventually, when the user has completed the boat, a next island can be made available to explore *(fig. 8)*.

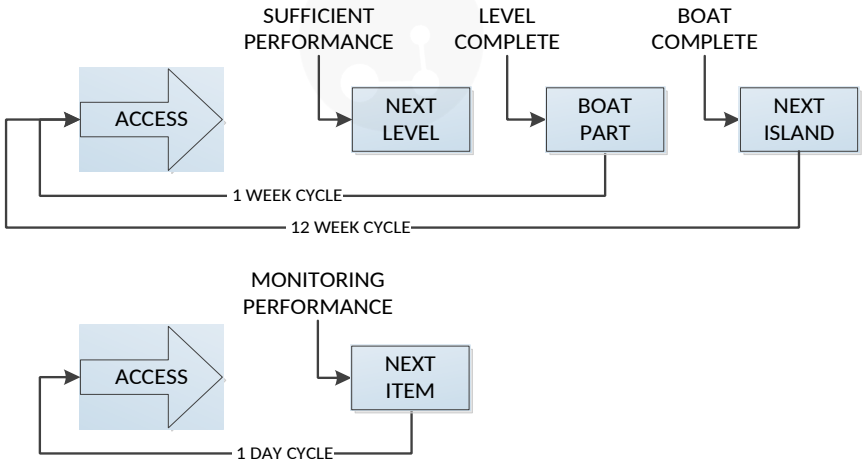

Figure 8 -Flow chart of the game progress of Stranded!

The game environment is built up from several scenes. Major locations are:

- An overview screen, or map, of the first island (birds-eye view)
- A two-part landing page or home screen which (like the portal) gives access to the modules as well as the pier where the lifeboat is constructed.
- 12 in-level screens such as mini-games and representations of the modules for monitoring and nutritional advice

The player starts at the home screen in each new session. When the game is started for the first time, an opening animation will show that introduces the backstory. From here, the training modules can be accessed directly through small wooden cabins. The scalable aspect of the game layer is realised through these wooden cabins, which can be added or removed to suit the training advice of the end user. The screen pans if the player walks to the left of the beach, showing another cabin that is connected to the monitoring module as well as the boat pier. From the beach, the player can move to the island in bird eye view. This map of the island will in time reveal new locations, in which mini games with each their own levels and graphic concept can be played. The first version of the game layer is expandable with more map areas and levels in mini games. The monitoring layer interacts with the game environment through the arrival of messages in a bottle which contains items that can be stored in a trophy hut, reflecting the overall timeline and monitoring achievements of the user. A social component for a future version could be added by adding the function of taking snapshots of scenes and environments that can be shared with others. The cycle of 12 weeks can be prolonged by extending the storyline to a second main location or island.

3.3.4 Concept art

Concept art covers the visual and auditory outline of the game, including graphics, animations, and sound design. Results in this section are style mood boards and interface mock-ups, graphic level (mini game) themes, character drawings, animation storyboards, game music compositions and sound effects. A summary of concept development is given in Multimedia Appendix 1. Intro and outro animations can be seen in Multimedia Appendix 2.

3.4 Phase 4 – Refinement

3.4.1 Prototypes

The final prototype was created through an iterative prototyping and evaluation process. The initial version is the result of the research described in Phase 1 as well as rigorous playtesting with the developing team and researchers. In each playtest, the full game was played, and all functionality was checked. The functionality of the game was constructed and tested using simple visuals, that are exchanged for mock-up images and, when finished, a final graphic design *(fig. 9).* Multimedia appendix 3 shows screenshots of these development cycles. Three more evaluation sessions, with end users, led to the refined final version of the prototype. An information point providing short explanations on items and functionalities on screen (i-icon in the corner of each screen) was created. Lastly, information was gathered on refining future versions (in the maintenance phase) as well as preliminary implementations for future functionalities.

Figure 9 – Final graphic design home-screen

The main character is a female explorer named Sophie: a likeable character that fits the storyline well, rather than a character that resembles the player itself. In the opening animation, we see Sophie on board a ship that is caught in a storm. She falls overboard when a sudden wave tilts the ship, and she washes up on the beach of a seemingly desolate island.

Every session starts with the choice of a classic or a gamified portal using a slider. The player starts on the right side of a panning scenery showing a beach. The player can start exploring the area and access huts which are directly connected to the training modules. The user can access a virtual crop field and cooking area (‘moestuin’, to be paired to nutritional advice), the rest of the island allows to explore mini-games (‘naar het eiland’) or to the left side of the beach where the boat is built (‘boot’). Items that wash up on the beach in bottles and some interactive surprises (or ‘easter eggs’) which are crabs were created. These crabs seem to be non-interactive, but after some trying it appears that they can be caught. These bottles are the main feedback from the monitoring module. Some contain seeds that are earned from training and through monitoring sufficient exercise which can be planted and grown in the crop field. Once harvested, they can be used to cook meals. The left hut is opened and leads to the physical training module. The other huts are constructed to be coupled with the nutritional and cognitive modules.

The island map displays six levels that can be played, which have been opened by means of completing training or exercises. After finishing each level, a piece of the lifeboat will be added to the construction. The image shows the progress after approximately two weeks of practising and playing.

3.4.2 Evaluations

Evaluation round	*Number of*	*Of which regular*	*Mean age*	*Male*	*Female*	*Overall appreciation*	*Ease of use*	*Expected effectivity*	*Fun and*	*Intended future use*

	participants	*players (weekly-daily)*				*game*	*application*	*and motivation through game*	*application pleasantness of using the*	
1	13	9	69	7	6	n/a	n/a	n/a	n/a	n/a
2	12	7	69	7	5	73 %	73 %	61 %	76 %	64 %
3	10	9	69	5	5	74 %	73 %	63 %	73 %	67 %

Table 2 – Summary of the results of evaluation studies

From the log files of the first evaluation round was observed that 9 persons explored the game without playing actively before returning to the use of the standard platform. Among reasons given were computer issues (n = 1), looking too complicated (n = 1) and distracting from the original exercises (n = 1). Two participants indicated to have forgotten about the game, and that they would like to get another chance. The game was played in combination with the underlying physical activity training module by 4 participants (2 male, 2 female) for a longer amount of time (1 to 6 weeks, one person weekly and three persons daily). Of these participants, 3 were frequent players. The appreciation for the game ranged from mildly to extremely enthusiastic. Two people indicated they were highly motivated to do the exercises because of the game. None of the participants were interested in playing the game together or sharing their progress. In the game, the storyline and the overall gameplay were the factors that appealed most to the participants, while the in-game explanations were found too limited. Two participants found the level of challenge in the mini games just right, one found it too difficult and one too easy. The controls of the game were not found sufficiently intuitive to use.

Using this information, pop-ups with short instructions or explanations on the current section of the game, which can be always recalled by clicking on the info icon in the corner of every screen, were implemented. Also, the mini games were given a tutorial through a very easily solvable first level with detailed explanations. The controls of the main character were revised to make them easier to understand and activate, by reducing moving around to just one click or tap on the screen.

In the second round of sessions, the game was played from beginning to end using instructions from the researcher. Participants indicated that the mini-games (n=5) and gathering boat parts (n=4) were the game's best features. The gamified platform (including the exercises) would be recommended to peers by 7 participants, and 8 would like to play the game again in the future. From the analyses of video (thinking aloud method) and screen captures, we observed that the explanatory text of the mini games was skipped by most participants. One of the mini-games controls was not understood at all because of this. Participants said they did not want to take time

to read the texts or thought they would understand the games without the explanation. None of the participants returned to this information afterwards but was inclined to give up without trying.

After this round of sessions, minor usability issues in the game were solved. The mini games had several unclear aspects that appeared to be caused by the explanations not being read. Therefore, the introduction to the (new) mini games was improved with shorter and more clear images. The one mini game that could not be played by most participants were fully replaced by another game.

In the third and final round, the prototype game was used in the daily living environment for six weeks, again using simulated exercise. The scores that the questionnaire returned are very close to those of the prior session. Five people would recommend the gamified platform to peers, five people would recommend the underlying exercises to peers. One participant mentioned sometimes having difficulty starting the game and one found that playing was fatiguing for the eyes (no playing time mentioned). Six participants would like to continue using the game. Challenges and goals were appreciated by the majority of people and playing the mini games was again considered the most motivating aspect of the game. The crop field was appreciated the least. During the final evaluation round, no new usability issues emerged, and no further errors occurred that hindered the use of the online application.

As described, the perception and appreciation of participants on different aspects of game content were measured in each of the evaluation rounds (26 participants returned complete results). Answers were given using a 5-point VAS scale and transposed to percentages before analysis. The 95% intervals were calculated and visualised in a graph *(fig. 10).* This figure helps to gain insight into how the game content is perceived by the user, related to the appreciation of the user of this same content.

In our pre-studies, we noticed a clear difference between the measured perception (or interpretation) of aspects of a game that was tested and the measured appreciation for these aspects by the user. In testing the PERSSILAA game, the scores of perceptions and appreciation did not show such large discrepancies. The difference between the two average values for each of the domains (as explained in section 3.1) was smaller than 4/100 for all domains except dedication and social, for which the differences were around 20/100. We therefore carefully assume that the guidelines we set in concluding the end-user research described in section 3.1 have helped us create attractive game content for the (computer literate) older adult user. As stated earlier, the social component deserves further exploration.

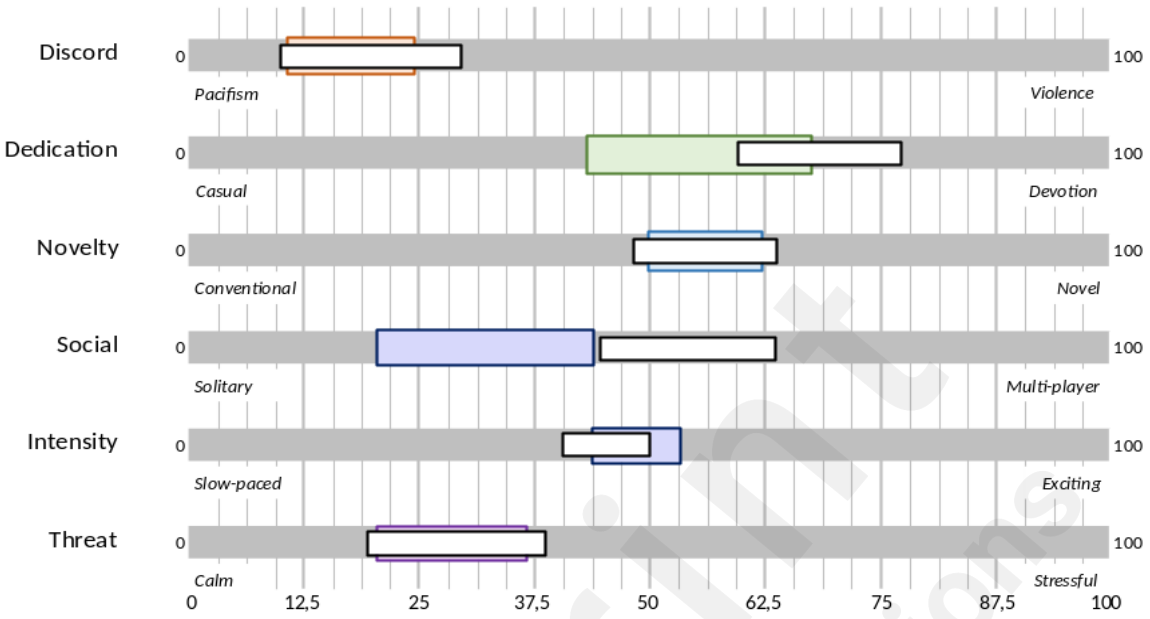

Figure 10 – User profile (perception: taller solid bars, appreciation: shorter hatched bars)

Discussion

This study provided insight into the development of game-based eHealth in practice from beginning to end. We hope that this article aids researchers and designers of future game-based applications. We introduced four phases in the process towards game-based eHealth; end-user research, conceptualisation, creative design, and refinement. These phases can be integrated into general system development cycles (as e.g. [49,50]) or in specific frameworks for the development of eHealth applications [51]. Our case study demonstrated the application of the proposed game design process and resulted in a complete game-based eHealth application. Furthermore, user evaluations of the prototype application indicate that results from end-user research and consequential strategies for long-term engagement led to game content that is engaging to the older adult end user, supporting the value of our approach. We believe that by offering transparency on our approach of the design process and by providing practical examples we contributed to opening the black box of game design that supports engagement in these applications.

Game-based design process: limitations and future research

Our iterative, four-phase method for game design gives prominence to the development of the actual game content within the overall eHealth application development. In a practical sense, however, such methods may also pose difficulties, as related work shows. For example, Hussain et al. state that priority conflicts arose from stakeholders less acquainted with agile approaches [52]. In our case study, we recognised this issue and responded to it by prioritising stakeholder influence in the design process in advance. This helped ensure that creative game design was given the necessary consideration and prevent being overshadowed by technical requirements or demands from the healthcare perspective. While satisfying each stakeholder, space was created for the creative process leading to designing fun and attractive game content.

From applying the game design process in practice, we learned that engagement is subject to many prerequisites. For example, not only the content of the application itself must be engaging, it must provide added value over the use of the underlying application alone, usability should not form a threshold, the game must be well-designed and well-made, and so on. However, end-user

characteristics are also influential. We find an ‘ideal’ end user for game-based eHealth to be open to the technology, able to work with this technology without extensive instruction and support, and preferably enjoys games and play. Furthermore, eHealth can play a supporting role as this user intends to work on the health objectives offered [53]. Participants included in our studies were ideal users: able to use the devices well and open to games and technology for use in eHealth. Therefore, they stand as models for the older adult of the future rather than being representative of older adults at the time of writing (2018). The game based PERSSILAA platform and design recommendations are therefore no guarantee for success when applied to use situations with different (healthcare) objectives or population samples. Repetition of the game-based design process as presented can (and should) lead to different requirements for game design when applied elsewhere.

Case study: limitations and future research

In the case study, the game-based version of the eHealth application was evaluated in a simulated setting (phase 4 of the game design process: refinement). The full roll-out of the finalised product will occur after concluding the game-based design process, in the implementation phase *(fig. 1)*. The performance of the game environment in terms of motivation and engagement must be explored in its actual use situation in future studies. Pilot testing may lead to new insights affecting any of the prior development cycles. Follow-up research topics may include both evaluations of the developed game-based application, in terms of user experience and satisfaction in real-world settings (including real exercises). Also, exploration of future functionalities, in terms of social interaction, user-generated content and expansion of existing features for prolonged use times may contribute to sustaining engagement over time.

Results from phase 1 (end-user research investigating game preferences of end users and specifications from the use context of the envisioned application) indicated that the obvious gaming preferences of the older adult based on current gaming behaviour (e.g., Scrabble and cards) may not lead to successful concepts for game-based eHealth. As eluded in the introduction of this paper, we therefore approached investigating potentially engaging content from the context of entertainment games and game design [31]. While these are not restricted by underlying ‘serious’ goals and purely aim for a satisfying experience, future research should focus on gathering additional knowledge on how to determine preferences for game content in end users, to be used in current and future game-based or gamified eHealth applications [54].

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Author Disclosure Statement

The author declares that no competing financial interests exist.

Multimedia appendix

1. Overview of concept art
2. Game animations (intro and outro)
3. Screenshots prototype phases (images 1.1-1.3, 2.1-2.3, 3.1-3.5)

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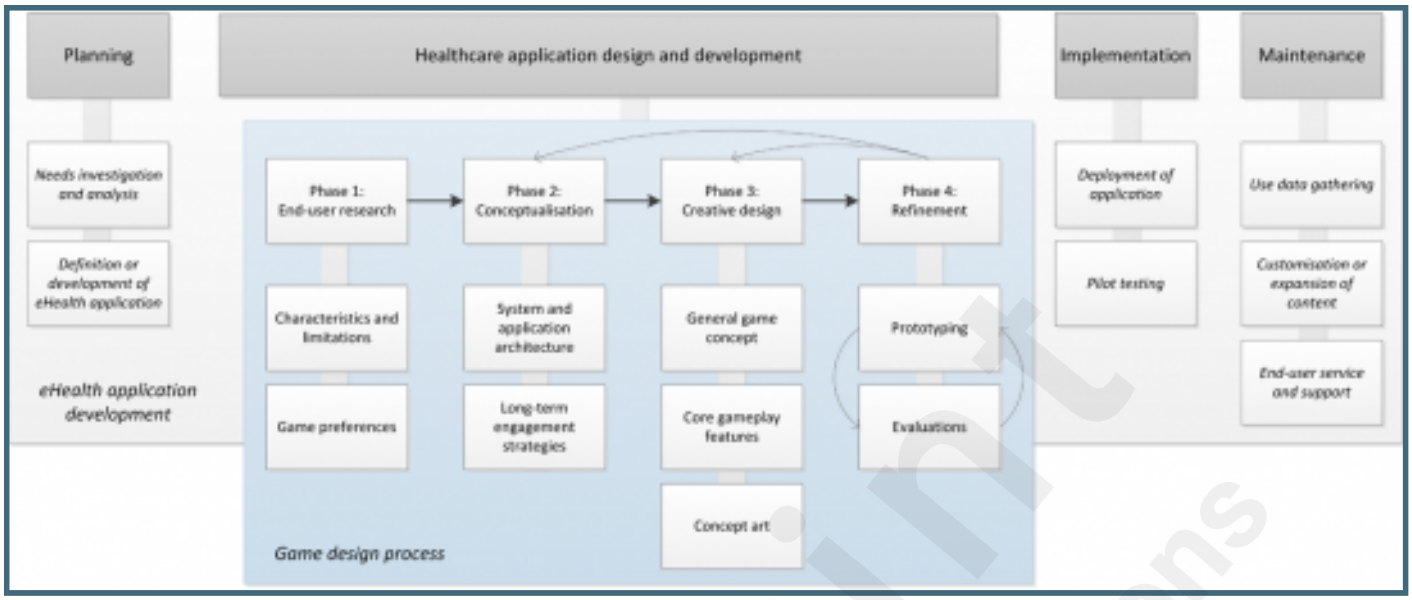
Supplementary Files

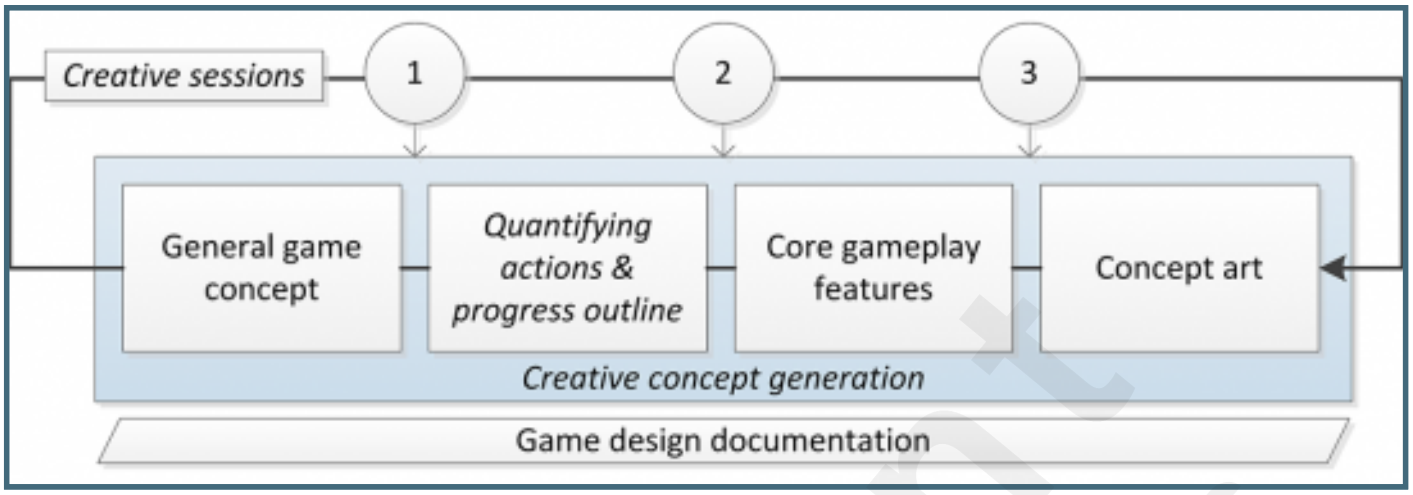
Untitled.
URL: http://asset.jmir.pub/assets/9ab686939735e1a0eabf32458d567a0d.docx

Figures

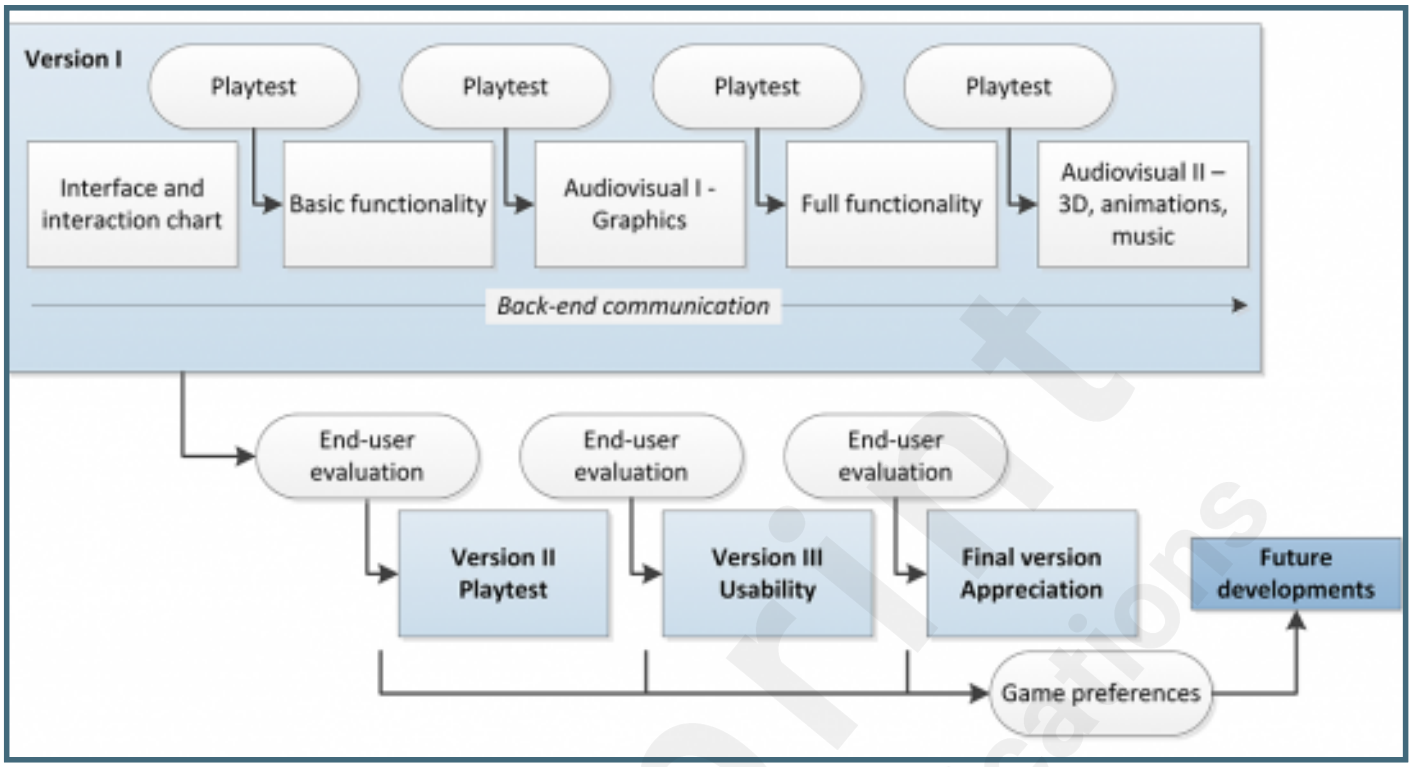
Game design process within eHealth application development.



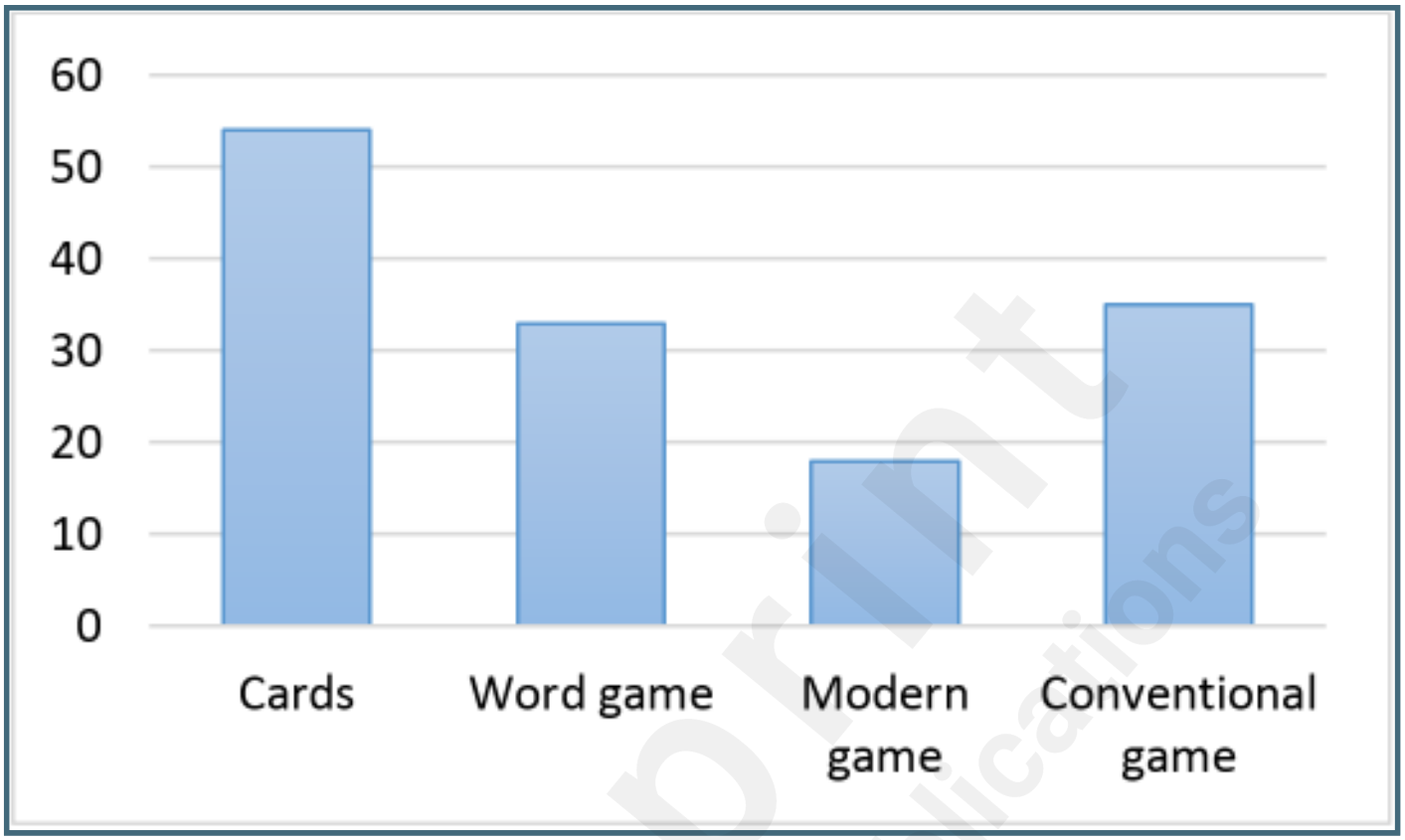
Game design phase (as applied in case study).



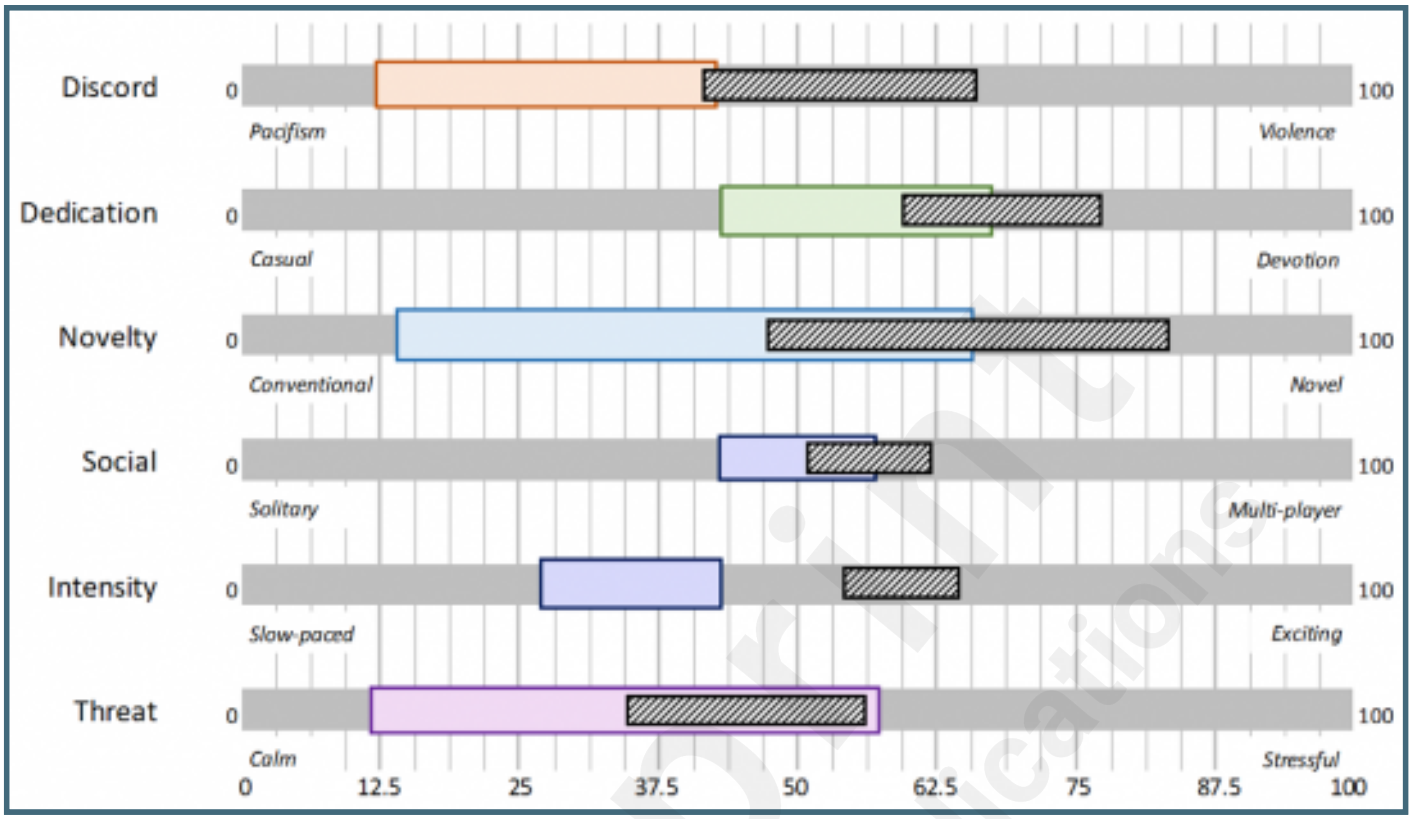
Refinement phase (as applied in case study).



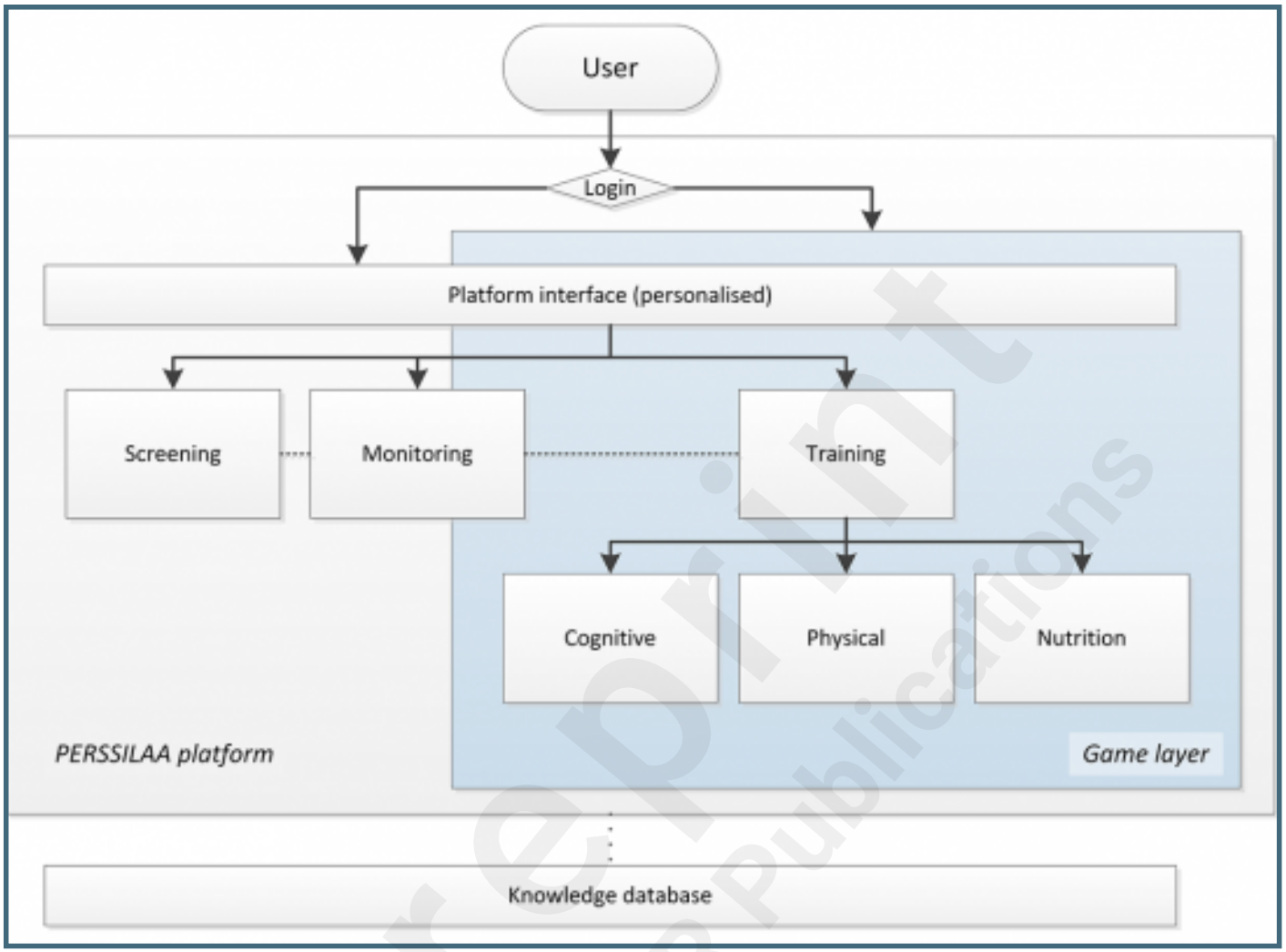
Participants’ current favourite games.



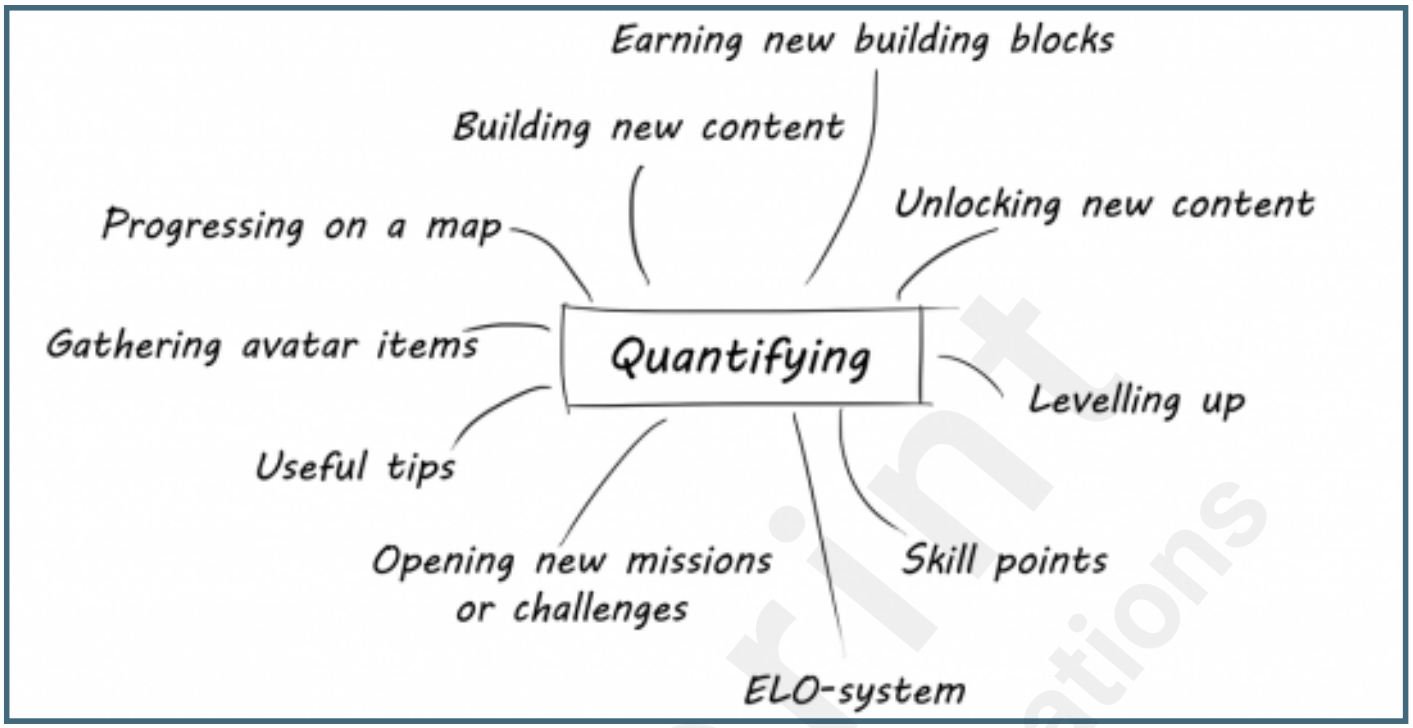
User profile (perception: taller solid bars, appreciation: shorter hatched bars).



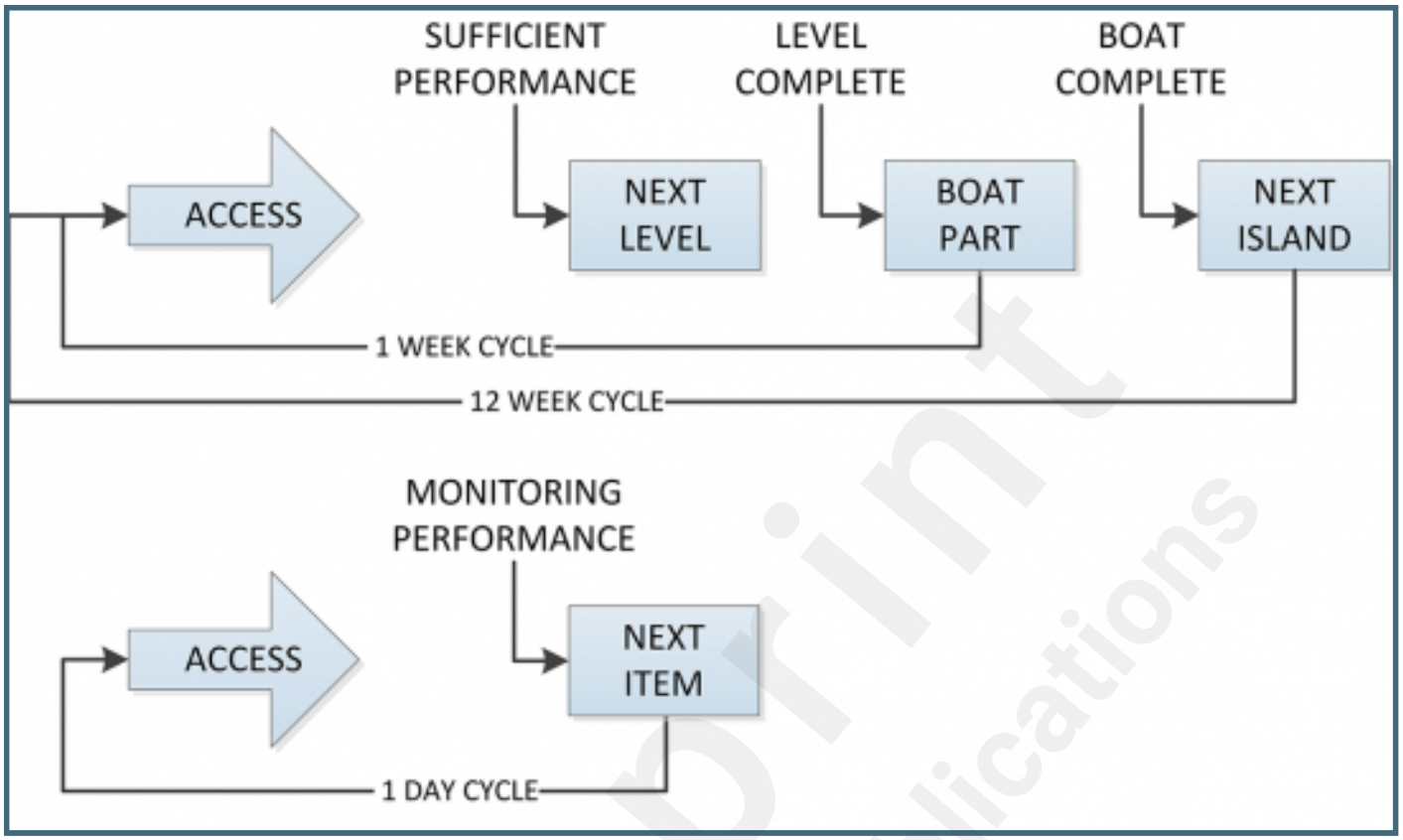
The PERSSILAA system for the older adult end user.



Mindmap.

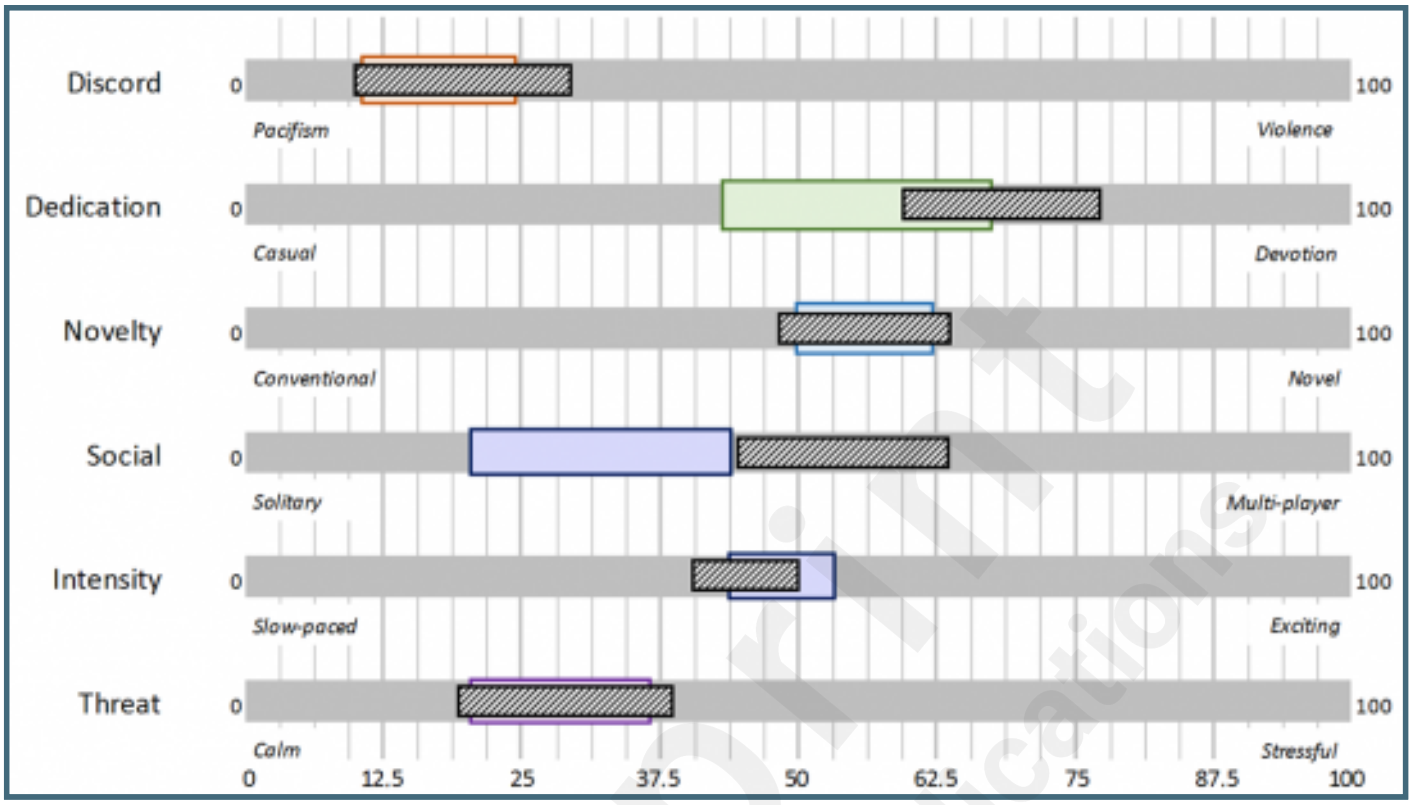


Flow chart of the game progress.



Final graphic design home-screen.

User profile (perception: taller solid bars, appreciation: shorter hatched bars).



Multimedia Appendixes

Overview of concept art.
URL: http://asset.jmir.pub/assets/3a8f9e61ef03c2aab7f8a1a55fc03579.png

Game animations (intro and outro).
URL: http://asset.jmir.pub/assets/2619dcd7f6748f008ad95c02fd7e520a.zip

Screenshots prototype phases.
URL: http://asset.jmir.pub/assets/ca6263962ae046100b646d332d854ba5.zip