A Framework for the Application of Participatory Design with Agile Game Development in a NUI Game for Wheelchair Users

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ABSTRACT

Wheelchair users benefit from Natural User Interface (NUI) games since the movements proportioned by this paradigm of interaction improve their social, physical and psychological skills. Previous studies showed that considering personal values and the social context of those users into content improve their acceptance for games. Participatory Design (PD) encompasses techniques that allow absorbing and reflecting values and the social context of users into software content. In this study, we employed PD techniques with mixed aged manual wheelchair users to develop a NUI game. We structured a framework that provides significant freedom to users to express their values and needs. To manage the application with the provided freedom, we included concepts from Agile Development and the Creative Process. We tested the acceptance of users for the developed game through quantitative and qualitative analysis. Our results indicate that the application of our framework can assist developers to create NUI games that reflect the perspectives of groups of users, consequently improving the acceptance from groups with similar characteristics.

Keywords: Participatory Design, Natura User Interface, Games, Agile SCRUM, Creative Process, Wheelchair Users.

1 INTRODUCTION

Wheelchair users handle various obstacles for conducting their lives, which often impact their life quality [13, 14]. Practicing exercises has been proven to develop physical, social and cognitive capabilities of wheelchair users [9, 16]. Furthermore, researchers showed that practicing exercises can lead wheelchair users to have a better life quality than non-disabled people [22]. Nevertheless, in the current social context, wheelchair users have reduced opportunities to participate in group physical activities [9, 16, 18]. Researchers have been tackling this issue with the development of exergames, in which users do physical exercises while interacting with the mechanics of the game [11, 16]. Interaction of exergames often employs Natural User Interface (NUI) through motion capture [31]. There is scientific evidence that people with disabilities, including wheelchair users, demonstrate motivation to practice solo and group exercises through interaction with NUI based games [29].

In previous work [29], we described the panorama of the research involving people with physical disabilities and NUI based games developed until the year of 2015. Most of the gesture-based games have their main focus on the development of the rehabilitation of the users [29]. Examples for rehabilitation are games whose user interface is structured upon the necessary movements for physiotherapy after a stroke or cerebral palsy. We observed that there is a low number of games that focuses on the inclusion of people with physical disabilities into society. An example for inclusion is a game the user interface of which is built in a way that allows people with an amputated arm to play together with non-disabled people. Also, according to our previous work [29], up to 2015, there was no study whose main focus was on representing or expressing the *values* of those people in games.

In 2016, Gerling *et al.* [10] represented the values of young powered wheelchair users in the design of gesture-based games through the application of Participatory Design (PD) techniques. They addressed the value of the participant wheelchair users by interpersonal interactions through PD sessions. The gesture interaction for the developed game was based on a previous work [12]. The results, based on testimonials of users, showed that the acceptance of users towards the game was substantially satisfying with the representation of their values in content [10]. Similarly, our motivation to utilize Participatory Design tools is due to our objective to represent the values and the social context of people with disabilities into the process.

Game development frequently follows frameworks within the Agile Software Development paradigm [19, 26]. Agile *Game* Development frameworks have the focus on increasing the entertainment value of the developed game through iterative steps. Nevertheless, the processes lack tools to explicitly consider user values, regarding the game content as well as other aspects such as game mechanics [19, 26]. This lack inspired us to develop a framework based on the Agile paradigm and focusing on the users' values. Although in this article we present a case study of a single game, we believe the proposed framework can be applied to other games.

We explore PD techniques to optimize the representation of users' values and social context within the content of games. Our contribution is the gathering of those techniques in a novel framework and the lessons learned from its application into the development of a gesture-based game with manual wheelchair users. We based the framework mainly on concepts of PD [10, 12, 21], and consider aspects of Agile Game Development [6, 24] and the Creative Process [7,17,27,28]. We developed a gesture-based game following the guidelines of our developed framework and evidenced the lessons learned. We measured the acceptance of users towards the developed game with quantitative and qualitative analysis.

2 DESIGNING AN NUI GAME WITH WHEELCHAIR USERS

We have conducted five sessions of Participatory Design with wheelchair users and colleagues of theirs. The design process followed our interpretation of previous work [5, 10, 15, 18, 25, 32] and concepts of Agile Game Development [6, 19, 24] and the Creative Process [7, 17, 27, 28]. Considering the study of Pommeranz *et al.* [23], who got satisfactory results with PD sessions with 30 minutes, we also time-marked our sessions to 30 minutes. This amount of time can be changed in future studies. All the sessions were video-recorded to capture the information of the process as a narrative [10, 15]. The sessions were supported by on-line forums [8]. Our team consisted of ten participants: seven codesigners, henceforth named *non-researchers* and the first three authors of this study,

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henceforth called *researchers*. The non-researchers group comprised five wheelchair users and two of their colleagues. We recruited the codesigners among members of the tennis organization *CR Tennis Academy*, in the city of São Caetano do Sul, Brazil. The researchers acted as facilitators and developers in the process but also participated in design activities.

2.1 Session 1: Introducing the Framed Problem

Our framework initially required researchers to pursue an analysis of the population, social impact and used technology for the game to be developed. Our research is detailed in a previous work [29] and resulted in a problem framing: How to develop a gesture-based game for wheelchair users focusing on their values and social context?. In this session, we asked participants to freely talk about that framed problem for half an hour. Our objective was to capture relevant elements from the values and social context of the participants. The conversation flowed freely, and the non-researchers did not seem to worry about the final goal (the game to be developed in a further moment). The main topics that naturally appeared during the conversation were objects or events of interest of the nonresearchers, such as the sports that they play and obstacles of their daily life. As we determined a maximum time of 30 minutes for the interaction [23], we defined and conducted a Design Game lasting 30 minutes and with a theme focused on elements of interest of the participants.

2.2 Session 2: Cloud Map Building

We recorded the first session on video so that we could analyze it [10, 15]. In the analysis, we transcribed all the main elements that were verbalized in the conversation. We considered as main elements the substantives or verbs that represented relevant elements to the theme of the conversation. Supported by the software *VOSViwer* [30], we built those elements into a cloud map. Cloud Maps highlight and evidence the most relevant words from texts The maps also represent words that have a close relationship to each other. [29]. Figure 1 displays the resulting cloud map from this PD session. As a result, we developed a visual connecting the main words from the previous conversation. That map contained important, summarized information about values and social context of the participants. We used that information in further sessions to structure relevant user stories [19] that guided the development of the game.



Figure 1: Cloud Map generated from information collected in Session 1. The most relevant words are highlighted and located closer to words related to them.

2.3 Session 3: Generating User Stories

The goal of Session 3 was to combine into user stories the most elements possible on the cloud maps within the given time. The

non-researchers randomly read some items in the maps and tried to create sentences with those elements. We suggested that, while creating the sentences, non-researchers kept in mind the basic game elements: Mechanics, Technology, Story, and Aesthetics [25]. The stories did not necessarily use the exact words that are in the cloud map. Instead, we noticed that the participants were inspired by the words in the maps to create stories with similar words. For instance, the fact that the words *car* and *adrenaline* were present in the maps led to a discussion about including a *race* in the game.

2.4 Session 4: Prioritizing User Stories

The goal of the fourth PD session was to converge the user stories retrieved in Session 3 into the basic elements for structuring a Concept Prototype of the game. According to studies of Creative Process [17, 27, 28], after enough preliminary ideas created in the conscience, unconscious systems of human brain work on those preliminary ideas to generate a main idea. The emergence of the main idea is known as *Illumination* [17]. Between the third and fourth sessions, we did not interact with the participants to allow subconscious idea generation. We understood that the session successfully reached its goal because the information collected in it was enough to develop the Concept Prototype. The convergence of the collected information in the other sessions marked the Illumination event and the transition from the Concept to the Pre-Production phase.

2.5 Session 5: Enhancing the Game's Interface based on Users' Values

Session 5 was based on the methodology of Sprint Reviewing in Game SCRUM. Along with the non-researchers, we decided which features of the game could be enhanced with the experience that we acquired. We enhanced game features to increase the playing experience in general. Moreover, we detected with the non-researchers the necessity of including features to evidence their values in the game. At this point, we could group the values in three main categories: (1) Empowerment, (2) Non-Competition and (3) Motivation. We detail about each one of them in Section 4. We developed the reviewed game during the Pre-Production Phase of Game SCRUM. Therefore, we considered it a Pre-Production Prototype. The developed game was named "Wheelchair Jecripe", as a continuity of the works from the JECRIPE (*Jogos de Estímulo Criados para Pessoas Especiais*; Portuguese version for "Games for Stimulus Created for Special People") Project [1–4].

3 EVALUATING THE EFFICACY OF THE FRAMEWORK

We experimented the Pre-Production Prototype of our game with a population of N = 19, divided into two groups. The first group consisted of four members of the codesigners non-researchers: two wheelchair users and two non-disabled users, three female and one male, aged 58, 53, 26 and 34. The second group comprised 15 participants that did not participate in the Participatory Design Process. This group contained seven wheelchair users and eight nondisabled users. All the non-disabled users were relatives or colleagues of the wheelchair users. Seven were female, and eight were male. The average age of that group was 32 years, ranging from 10 to 60 years.

The participants filled a five questions pre-test questionnaire, played the game from 15 to 20 minutes and filled a 19 questions post-test questionnaire. We have also registered testimonials and observations from the participants. We only interrupted the test to provide the first explanation on how to play the game and in the case of software or hardware problems. The experiment had the approval of the *Federal University of ABC's Ethics Committee*. For the participants that did not have physical or cognitive conditions to fill in the questionnaires, we asked their parents to answer the questions.

For our analysis of the results, we created boxplots from the questionnaires and also considered the testimonials of participants. Figure 2, for instance, displays the boxplots of the players' immersion level based on the ITC-Sense of Presence Inventory [20]. Figure 2 reveals that, even though the developed game was in a prototype stage during the test, most of the participants experienced a satisfying immersion level, close to 9. To estimate the acceptance of participants for the game, we evaluated metrics such as learnability, immersion, enjoyment or fatigue. Then, we compared the acceptance of those groups (codesigners and non-codesigners with similar social context) for the game.



Figure 2: ITC Score Boxplot Graphics: The graphs compare the dispersion of results from the immersion level for the codesigners and non-codesigners in the game.

4 DISCUSSION

The chosen methods clearly enabled the participants to influence the design process, *e.g.* by defining and prioritizing the user stories or by redefining the used input gestures. One goal of the design process was to create a game that could improve the quality of life of players by increasing their self-confidence and by encouraging them to conduct the activities portrayed in the game or other sports activities in the physical world. Although it is too early to make strong claims, participant testimonials indicate the game's potential to reach this goal. Regarding the context or use situation, we recruited participants that are already active sport practitioners, in this case, Tennis. For future iterations of the framework, practitioners of other sports could be included, as well as people who are less active and even practice no sports at all.

The Creative Process concepts were crucial to our work to support the elicitation and discussion of values and social context of users. Based on the Creative Process, the activities were structured to promote the creative and effective participation of the nonresearchers codesigners. As a result, we developed a game that had a satisfying and near homogeneous acceptance of a population with similar player profile. Therefore, we believe that the used tools and techniques successfully leaded us to represent those people's values and social context into the game.

The Game SCRUM concepts were important to manage the process with flexibility for non-researchers to express themselves. We realized that user stories were a simple technique that allowed the non-researchers codesingers to express user experience related aspects in a way that could be understood and used by the developers. Moreover, structuring the framework on Game SCRUM avoided workload being applied into elements with low value to the game. As a result, we could develop a lean, but effective game. We display a graphical scheme of the framework in Figure 3.

We detected three main values that were "designed into" the pre-production prototype: (1) Empowerment of wheelchair users by representing the wheelchair in game as an apparatus to enroll



Figure 3: Flow of the framework stages during Game Development: The framework stages overlap with Game SCRUM phases and Creative Process' events.

in interesting activities instead of a tool to supply a special need, (2) Non-competition in game to amplify the friendly atmosphere of the game, and (3) Motivation in terms of encouraging players to enroll real life activities similar to those depicted in the game.

5 LIMITATIONS AND FUTURE WORK

We detected that the circumstances in which we developed the game and applied the tests potentially influenced in the results. Due to schedule restrictions of non-researchers, all the PD sessions have taken place after their training. As a consequence of the exercises practice, the mood of those codesigners was frequently high. Even though the relaxed atmosphere supported us in conducting meetings with a good flow, we suggest potential next sessions being performed in varying situations to avoid external aspects influencing in the capture of information. Similarly, due to restrictions of resources, we, the developers of the game, were responsible for applying the playing tests during the experimentation of the study. Even though we focused on being as impartial as possible, potential sympathy created between the participants of the test and us could have led the results to be influenced. In future work, we suggest the tests being applied by people with no relationship with the developers of the game.

The main contributions of this study are the framework that we developed and the lessons learned from its application. Nevertheless, we believe that we can improve the developed game based on the results and testimonials retrieved in the experimentation. Even though we understood that the prototype of the game reached its objective in representing values of the users, it can be adapted to encompass a broader public. Possibly, the next group of people to be involved by the game content are wheelchair users with more limited function abilities than the users that participated in the development of the present work. Moreover, we believe that algorithm for capturing the users movements can be optimized to provide a more refined response. The potential improvements in the algorithm leads to more research being performed in the field of Computer Vision.

6 CONCLUSIONS

We structured a framework to explore and evidence values and the social context of users during the development of a NUI game by means of gesture-based interaction for wheelchair users. The framework addresses the users' values and social context in Agile Game Development with Participatory Design techniques. We based the framework on Agile Game SCRUM, which is one of the most popular Agile frameworks for Game Development. The PD techniques that we included in the framework were the Design Games and the Guidelines in PD for people with disabilities. Those techniques focus respectively on minimizing misunderstandings during PD and including personal characteristics of users into the content of the game. Consequently, the acceptance of users with similar social context and player profile for the resulting game was positive. As future work, we propose more tests and applications of the framework with different conditions to continue exploring its efficacy.

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