An Approach to Make Software Testing for Users with Down Syndrome a little more Pleasant

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ABSTRACT
Evaluating software with users implies challenging tasks where users' abilities are sometimes taken to the limit. This process might turn a very unpleasant experience to users susceptible to anxiety and stress, such as users with Down syndrome. By consequence the poor performance of unpleasant users generates unreal results. We propose a gamified approach for software testing, which allows maintaining user's motivation and engagement with the test's activities, reducing anxiety and stress, having by consequence more reliable results. The gamified approach can be applied on any kind of software testing involving users, since it works over how the activities are presented to participants, once they have been defined according with the test goal. Results of the application, over 10 users with Down syndrome, suggest that the gamified approach maintains the emotional state of users in a positive way even when they made errors, got confused, or were forced to change/stop an activity.

Author Keywords
Human factors, Accessibility, Disabilities, Evaluation.

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1. INTRODUCTION
It is known that software developers and designers must know how their products cover all needs of goal-users. User evaluation of software products has shown to enhance user-needs fitting in usability, accessibility, ergonomics and learning; software evaluation involving users means analyzing the way users interact with it, and it is one of the most important aspects of User Centered Design [1] [2].

For some users the experience of being tested may turn unpleasant; in fact, all software testing involving users generate certain levels of anxiety and stress, but there are users that can deal with them better than others. Klemmer explain that users might feel uncomfortable during evaluation due to [3]:

- Compromising to make things well
- Feeling of being observed
- Challenging of capabilities
- Error making afraid
- Changing of the ordinary working space

Users' discomfort may affect their performance in evaluation and reliability of resulting data. This is main the reason of why is important to provide a friendly evaluation environment to users. The last evaluators want is that,

besides the effort made to use the product, users also endeavor to be comfortable with the strangers in an unknown observation room. Enhancing testing experiences, allow a deeper understanding of learning strategies and preferences of users [4] [5], and enhance reliability of the study results.

This research presents an approach to evaluate software, based on gamification ideas -bringing the game experience to software evaluation. It allows maintaining the user's motivation and engagement, reducing anxiety and stress, during the whole testing process, and takes especially care of the Down syndrome users' characteristics in communication, socialization, and behavior.

The reminder of this paper is presented as follows: Section 2 presents the theoretical basis, including User testing, gamification and challenges in testing software products with Down syndrome users. Section 3 presents the research methodology to solve the problem. The proposed approach is described in section 4. Results are presented in section 5. Finally, Section 6 presents conclusions and future work.

2. THEORETICAL BACKGROUND

2.1 Gamification

Gamification is about including the game thinking in non-gaming scenarios to change people behavior, i.e. to make activities more or less game-like in non-gaming contexts [6] [7], [8] [9] ; but more than creating a game, gamification is creating a gamified experience in an optimized way [9]. Also, the gamification of non-gaming processes means making them more fun and engaging without undermining their credibility; among the benefits of Gamification there are [9] [10], [11]:

- Fun and pleasure
- Increase altruism
- Increase brainstorming and alternatives development
- Increase company loyalty
- Increase competition
- Increase effectiveness of learning
- Increase efficiency of learning
- Increase information dissemination
- Increase motivation
- Increase productivity
- Increase self-expression
- Increase skills
- Increase social capital
- Increase tasks engagement
- Obtain desired behaviors

In spite of all the advantages, there is a clear danger in applying Gamification in non-gaming process; if Gamification turns to be successful in providing *gameful* experiences to users, but they are distracted from using the core service, the whole process had failed [12].

One of the most used frameworks of game to apply gamification in non-game scenarios is referred as MDA: Mechanics, Dynamics, and Aesthetics [14] [15].

- Mechanics: The control mechanisms that rules the players' actions within a game context.
- Dynamics: The specific player actions and/or behavior triggered or motivated by certain set of game mechanics.
- Aesthetics: The desired behavior evoked in the player by the game, resulting by certain dynamics.

These three elements of game design help understand players and apply the required techniques to generate the desired behaviors on them. In shortly, mechanics are the core elements of the game that guide players' actions; dynamics determine what players do in response to the mechanics; and aesthetics is the resulted behavior that mechanics and dynamics generate in players [9] [14] [15] .

The MDA Framework helps designers to understand how the elements of a Game will work to generate certain behavior in players. The art of applying gamification in non-gaming scenarios is how these three elements work together to evoke the design behavior in users.

2.2 Challenges of Learnability Evaluation with Down Syndrome Users

Down syndrome affects physical, intellectual and behavioral capabilities in those who burn with it, affecting social interaction and work productivity [13]. Among the most common physical limitations of Down syndrome people there are difficulties in the fine motor skills, eye-hand coordination, eyesight, hearing. Around 80% of Down syndrome people have Intelligence Quotient average of 50, being in the rank of moderate intellectual disability [14], having commonly problems like low comprehension of abstract concepts, delay in expressive language, lack of concentration, problems in short-term memory, among others [15] [13] [14].

There are a few papers in literature that inform about the software evaluation with Down syndrome users, among the common behaviors reported by researchers are: easy distraction, limited concentration time, difficulty in understanding instructions, difficulty in following a set of instructions, being not cooperative to work, and spontaneous and impulsive changes of mood. Feng in [16] present a summary of difficulties experienced by Down Syndrome users using computers, among the most common are:

- Typing
- Frustration in navigation
- Frustration in trouble shooting
- Lack of patience
- Low error tolerance
- Frustration when excessive information was found
- Frustration in inconsistencies in interface design
- Frustration when there are too many windows opened

Authors of [17] and [4] gave an interesting list of good practices in evaluating software with Down syndrome users from two different cases of study:

- Be sure that users understand what they will do, when and what they would get when done; also explain them the kind of help they would get if needed.
- Visual learning strategies works better with Down syndrome users, take special care in the visual design of the test.
- Take care in detail, individuals with Down syndrome methodically scan every piece of information, every variation in design will be interpreted in some way.
- The time of attention in a particular activity is around 10 to 15 minutes
- Use real examples
- Be flexible with participants
- Anticipate material required in testing
- Present satisfaction scales visually
- Instructions should be provided visually and verbally
- Create attractive tools to the study

3. METHODOLOGY

To implement the gamified approach into the software testing process, we have defined the next steps:

1. Defining the user test
2. Defining gamification
3. Construction of the player journey
4. Applying the user test

3.1 Defining the user test

The main goal of the user test was to provide information about how users interact with an unknown mobile application; knowing that such experience could be unpleasant to users with Down syndrome. A great environment to test our ideas.

All activities were made over a mobile application called "Learn to read and write" v1.1.1 made by Endyanos-imedia and available in http://www.endyanosimedia.com/apps; running over a 10.1'' Samsung © Galaxy tablet computer with Android© 5.0.2 Lollipop.

Three tasks were defined the test:

1. Interaction with the reading part of the app: Listen the letter and the word by touching the figures and use the "next" button to do it with the first five letters.
2. Interaction with the writing part of the app: Paint in the blackboard following the writing pattern, erase, and use the "next" button to do it with the first five letters.
3. Interaction with the app: Close the current window, change between windows, open new window from the main menu, close the app, and open the app.

For the application of the test, the next roles were involved:

- Applicator: Guides the users throughout testing, gives all the instructions and provide necessary help.
- Assistant: Helps applicator in several tasks, such as configuring the environment, providing material, setting devices, etc.
- Psychologist: Evaluates the users behavior during testing analyzing the recorded video.

The next variables were measured:

1. Percentage of users that successfully completed each task at first try.
2. Percentage of users that fail in completing each task.
3. Average number of trials per task.
4. Average time expended to each task.
5. Initial and final emotional state

3.2 Defining gamification

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According MDA framework, a set of Aesthetics most be defined based in the desired behavior; for the current test the next were defined:

- Willing to start a new activity
- Confidence with the test applicator and commitment with the study
- Concentration and attention to the instructions
- Concentration and attention in making the task, commitment in making the best effort
- Pride in the effort made

Then, the corresponding game Dynamics most be also defined. There are lots of dynamics in books, specialized websites, blogs, etc. We took those that directly correspond with the Aesthetics previously defined:

- Happiness and Joy: To motivate the users to start this new activity, no matter what they were doing, we must make them feel that this is a more amused and fun.
- Affective bound: Creating an affective bound between the user and both, the applicator and the study, will result in trust and commitment.

- Clear understanding: We motivate in users their willing to pay attention to the set of instructions of a particular task, in order to facilitate their comprehension and let user to have a clear idea (Figure in the Gestalt cycle) about the effort required to accomplish it (Energy in the Gestalt cycle).
- Working hard: In this game Dynamic motivate the users' willing to work, providing them self-confidence and enhancing concentration.
- Rewarding: We reward all users' effort, making them feel proud of the work they made.

Finally, the MDA framework suggests defining the game mechanics in accordance with the desired dynamics. There are also lots of game mechanics available in very different sources; we took the next six:

- Discovery: Encourage users to discover something, to be surprised.
- Avatar: A fictitious character that is affected by the player actions in the game-world. Avatars give the opportunity to create a commitment with the player.
- Epic meaning: It enrols player to believe they are working to achieve something great, inspiring, bigger than themselves.
- Cascading Information: Provides information in the minimum possible snippets to gain the appropriate level of understanding.
- Permission to fail: It gives the opportunity to player to make mistakes with no point loss. Motivates player to do what he/she can without fear to lose.
- Badges: It is a label of distinction for certain qualities of the player during the game.

Table 1 shows the content of the MDA framework defined for this test.

Table 1: The MDA framework for users testing

Mechanics	Dynamics	Aesthetics
Discovery	Happiness and Joy	Willing to start a new activity
Avatar Epic meaning	Affective bound	Confidence with the test applicator and commitment with the study
Cascading Information	Clear understanding	Concentration and attention to the instructions
Permission to fail	Working hard	Concentration and attention in making the task, commitment in making the best effort
Badges	Rewarding	Proud of the work done

3.3 Construction of the player journey

Games immerge players through a fantastic trip called the player journey. The player journey is commonly divided in four phases: Discovery, Onboarding, Scaffolding, and The end game [22] [23]; in the software test explained here, participants are guided mainly by the test applicator and with a digital dashboard that presents avatars, scenarios, badges and all other interactions that reflect the game mechanics and dynamics.

The dashboard acts as a presentation tool for the test applicator, were participant can see the consequence of their activities; but all participants actions are made over the mobile device all the gamifying *magic*, i. e. the actions that assure that mechanics and dynamics generate the right aesthetics, depends of the test applicator.

For the test here described, the journey begins with the invitation to users to participate. In this first step, the **Discovery** mechanic acts. Test applicator assures in creating in users willing to start this new activity.

Then, a welcome screen is presented, here participants select an **Avatar**: boy or girl. The selection of their preferred avatar, creates an **Affective bound** between participants and avatar, resulting in more commitment with the test. The test applicator explains to participants that the main objective is to help their avatars in collecting the more quantity of golden stars as they can. Each completed activity returns a golden star. Avatars need their golden stars to fulfill the universe with happiness (**Epic meaning**).

Now, participants start to do the set of activities described in 3.1, one by one. Instructions are only explained once to participants, test applicator use **Cascading Information** to do it, very punctual, very clear. It avoids information overload.

Participants can ask questions, to clarify any doubt and even abort some difficult activity, and no negative consequence were deflected on them or their avatar. **Permission to fail** gave the opportunity to receive the same positive stimulus no matter how the activity ends. When a participant failed, aborted or did not make an activity as expected, test applicator only changed the given **Badge**, instead of stars, for the current activity, participants could receive medals.

At the end of the test, participants received the not-acquired stars for their medals, and those who acquired all golden stars, received a medal for it.

The next table summarizes the four phases in the player journey:

Table 2: The player journey

Phase	Description
Discovery	Test applicator sensitizes participants to get involved in the test.
Onboarding	The participant becomes familiar with the activities of the test.
Scaffolding	The participant makes the test activities
The end game	The participants understand that there are not more activities to do, finalize all attention to the test but still have enough willing to do it again.

3.4 Applying the user test

Many data were coded during sessions, but a further analysis was applied over the video record. The protocol of the test was:

1. Users were received outside the classroom and test applicator prepare users to participate in the testing activities.
2. Participants selects an avatar and test applicator explain instructions of each activity as participants complete them.
3. Test applicators gives participants their proper badge at the end of each activity.
4. Test applicator close all the testing activity.
5. Test applicator call another participant.

4. EXPERIMENTAL WORK

10 users with Down syndrome between 15 and 20 years old ($\bar{X} = 16,\ S = 2.23$) were involved in this study; 4 women and 6 men, all enrolled in a special school program in the same grade. All of them have basic reading and writing skills and can develop a set of tasks derived from a set of instructions. Verbal communication is very limited. They have basic experience using computers, they usually play academic games using keyboard and mouse, and basic knowledge using tablet computers and smartphones; none of them interacted previously with the tested application. All participants' parents were provided with the institutional document of consent participation, based on the *Informed Parental Consent for Research Involving Children* of the World Health Organization [18], which informed and asked acceptance of the activities around the test.

All participants made the test activities three times each on individual sessions. Sessions were applied Monday, Wednesday and Friday in the same week. All participants were evaluated one by one, no one of them had interacted with the tested software before. As mentioned before, the test applicator motivated participants to start the test outside the classroom. All activities made over the mobile device were developed individually (figure 1).

Once participants were inside, they selected their avatar (figure 2). Personalizing the avatar, adding it personality and a name, for example, enhance the participants' commitment. Participants started to interact with the reading part of the tested application. Only one explanation was provided by the test applicator for each of the three activities defined in 3.1. When participants failed in execution, the test applicator motivated them to continue, to try again. When participants fail twice, they advance to the next activity. The assignation of badges was according with the terms defined in 3.3 assuring that, no matter the result, the participant emotional state must stay positive (figure 3).

Figure 1: Working in the mobile device

Figure 2: Selecting avatar

At the end of the three activities, users receive all stars required for the **Epic meaning** (figure 4). To close the game experience, the conclusion of the story was exposed by the test applicator and a videoclip was displayed.

Figure 3: Acquiring a badge

Figure 4: Acquiring all stars

5. RESULTS

The behavior of users was analyzed by a Psychologist with more than 20 years of experience working with people with intellectual disabilities. She checked out how users started and ended their participation, by considering three possible emotional states: Positive behavior (happy, cooperative, friendly, etc.), neutral (staid, calmed, inexpressive, etc.) and negative behavior (bored, angry, sad, etc.). These results are shown in the next table.

Table 3: Users' behavior change

	First Session	Final Session
% of users with negative emotion at the beginning of the test	40%	10%
% of users with neutral emotion at the beginning of the tests	30%	0%
% of users with negative emotion at the end of the tests	0%	0%
% of users with neutral emotion at the end of the tests	0%	0%
% of users requiring the behavioral control extra-actions	60%	20%

The Psychologist also coded the most common behavior shown by users at each stage of the testing experience. Table 4 shows a comparison between first and final session across the player journey.

Table 4: Users' behavior first vs final

Testing experience Stage	Behavior	
	First Session	Final Session
Discovery	Negative (40%)	Positive (100%)
Onboarding	Neutral (50%)	Positive (100%)
Scaffolding	Neutral (60%)	Positive (80%)
The end game	Positive (60%)	Positive (100%)

The errors that participants made in a software testing may indicate how difficult is to achieve some knowledge in an interface, so that in [19] is suggested to analyze the reason of these fails; authors defined three types of fails: 1) Due to the ability of the user; 3) due to misunderstanding of the task; and 3) due to the user gave up. The results for the failure analysis in our research is shown in the table 5.

Table 5: Failure analysis

	First Session	Final Session
Failed tasks	15	7
% of tasks failed due to task complexity	80%	90%
% of tasks failed due to misunderstanding	13%	5%
% of tasks failed due to giving up	8%	5%

After the definition of the plan study, we proposed to apply an ethnographic study over the goal population. Doing this we collect very useful data that help us in the definitions of further steps. Literature review about Down syndrome, interviews with participants' relatives, teachers and therapists, and our enrollment in curricular and extracurricular activities with them, summarize the activities made in the ethnographic study.

The gamification of the learnability testing process was relatively simple, since we had already known what behavior we need to evoke in users at which time thanks to the prior application of the Gestalt cycle of experience. These were taken as the game aesthetics, then we select the proper dynamics and mechanics, put them all together into a simple story and play it with users.

Analyzing results of users' behavior gave us the chance to explore how the gamification enhance the learnability testing process. Data of table 12 show how even users that began their very first participation in the study with negative behavior change it; having at the end of this first session the whole population of users finalizing it with positive behavior. Also, the percentage of users that required extra assistance in controlling their emotional state was reduce 40 percent, meaning that users feel more comfortable. This does not mean that users were always happy, but that gamification was working diminishing for example fear before making the tasks, creating independence from pleasant tasks, and overcoming fails.

The high percentage of failed tasks due to its complexity, in comparison with other causes, shown in table 13, let us see how gamification motivated users to keep working, maintained self-confidence and enhanced communication between applicator and users.

6. CONCLUSIONS

In this paper, present a way to make more fun and engaging a software test to participants with Down syndrome, since they commonly got stressed when confront a new and unknown activity, i.e. it turns to be an unpleasant experience. In other words, we created a friendlier environment to test software by applying gamification, successfully evoking positive emotions in participants, maintaining engagement, commitment, and interest during all the testing process.

According to experts, people with Down syndrome give up in difficult tasks, because they lost the interest or the motivation, they were bored, tired and even angry, and among a variety of negative feelings. They also commonly avoid challenge, they feel anxious and stressed in new situations with strange people, they have limited verbal communication and effusive behavior. We faced all these situations in our study, but they were successfully managed.

Besides all information derived from results we cannot despise the subjective appreciation of the study by users. We fortunately received many good comments by relatives of participants: *"what did you do with my kid yesterday? He was fascinated about this new class… he told everybody about it, all day long!"*, *"I thought tablet computers were a waste of time and money, but I'd never seen my boy so participative and happy to work!"*, *"… she actually learned the letters, she even practices them at home"*.

Finally, we derived a set of recommendations to researchers that face software testing with Down syndrome users:

- It is important to create a strong affective bond between the users and people that will interact with them (from the research team), to stop being strangers and affect users' performance and comfort.
- An affective bond with relatives, teachers and therapists will be as important as the one with the users.
- When users make mistakes, do not provide help immediately. Motivate them to continue working or close the experience by diminishing the error and enhancing the value of participation.
- Always remark the good things made by users in participation. Participants must be convinced that their work is worthy.
- Use badges instead of points. Medals, stars and coins are better rewards than numbers.

The next step in this research is to apply the gamified approach in more structured software tests involving users with Down syndrome; specially those with a clearly-defined process as usability and user-experience tests. It is also needed to define a more structured process for the gamification of software testing involving users, possible only when more experiments were done, and more data were analyzed.

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