Supporting Player Diversity: Game Interfaces for People with Disabilities

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Submitted to the ACM Student Research Competition Grand Finals 2013

ABSTRACT
Computer games are a very popular media today, spanning across multiple aspects of life, not only leisure but also in other fields such as education. But despite their social relevance their current level of accessibility is still low. One of the reasons is that accessibility has an additional cost and effort for developers that is in many cases unaffordable. As a way to support developers, we propose the creation of specialized tools to deal with accessibility. The hypothesis defined was that it is possible to produce tools that could reduce the cost and effort needed to adapt games for people with special needs while achieving a sufficient level of usability and a pleasant player experience. Because of the ambitious of the approach, the goal of the project is to explore if it is feasible through preliminary research. Three experiments were set up to cover and explore different alternatives, given the diversity of player characteristics and game development approaches. In these experiments we targeted two different platforms: a desktop game authoring tool oriented to educators, and a mobile game development framework oriented to programmers. In these experiments we used the tools developed to produce several games that were also tested by end users. While the project focuses on disability, the ideas proposed can be generalized and applied to support optimizing game interfaces for a wide and diverse audience.

1. PROBLEM AND MOTIVATION
Digital games have acquired extraordinary social relevance, becoming a very popular media in modern culture and life and constituting a massive industry of $16.6 billion per year in the U.S. alone (data from 2011) [5]. The popularity of digital games has resulted in a diversification of gaming, as new profiles of users are constantly starting to adopt gaming habits. This adds a burden for the developer, who needs to produce games that appeal to a wider audience.

Accessibility is one of the dimensions that create player diversity. There is a growing need for delivering game-play experiences that are optimized for users with different functional capabilities, especially in ageing populations (e.g. Western countries). But the current level of accessibility of digital games is low, with a small number of titles meeting the needs of people with disabilities [21, 23]. One of the reasons for this is, again, that dealing with the needs of people with disabilities is complex and involves significant extra work for the people who create the game.

As game development is already a very complex activity, our proposal is to explore how game development software can help the developer deal with player diversity, focusing on accessibility issues. The approach we describe in this project considers the (semi)-automatic adaptation of the gameplay experience depending on the characteristics of the player. The developer creates a base instance of the game, and then uses one or several tools to ensure different players will get the best experience possible. This approach is ambitious as the challenge is significant both from design and technical perspectives, raising two questions. First, it is unclear if the products obtained would be able to meet any quality criteria. Second: it is uncertain to what extent the effort required to produce adapted versions of the game may surpass the benefits in terms of cost reduction. The goal of this project was to conduct exploratory research to determine the actual feasibility of this approach. In summary, the next research questions are set out:

- RQ1: *Can (semi-)automatically generated interfaces deliver pleasant game experiences for a diverse target audience?*
- RQ2: *To what extent can game development software help reduce the cost of dealing with diversity?*

This project also considers other aspects of diversified gaming that have a considerable effect on the developer: the diversity of gaming platforms, development approaches, and applications.

As a limitation, this project only considers adaptation of the game interface. Adaptations related to the game design, content or flow are left out of the scope. As a result, only physical disabilities are considered, as barriers found by players with cognitive disabilities are usually related to those aspects.

2. BACKGROUND AND RELATED WORK

2.1 The Diversification of Gaming
This increased popularity of gaming is resulting in a diversification of the players. Segments of the population that did not use to show frequent gaming habits are now present in digital game usage figures. For example, in 2006 [6] gamers were unevenly distributed between males (62.0%) and females (38.0%), while in 2012 the difference has trimmed almost to zero (53% males, 47% females) [5]. The population of gamers is ageing as well. In 2011 29% of gamers were over the age of 50, in contrast to the 19% this segment represented in 2004 and the 9% in 1999 [7].

Gaming is also experiencing a *diversification of platforms*. Mobile devices have managed to capture a significant market quota and gaming devices are constantly evolving. Finally, there is also a *diversification in the application* fields where games are used. Currently digital games are not only being used for entertainment, but also in education [11], for advertising or health [2]. For the developer, this makes more difficult to get the player engaged.

2.2 The Importance of Accessibility
Accessibility is no longer a problem that affects a minority of the population. Instead, considering accessibility in the inception of the design of any product or technology may favor us all, especially in Western countries where populations are ageing

rapidly. The same features that enable using a computer for a person with limited vision could help us when we get old. There are also environmental or contextual factors where anyone could take advantage of accessibility features. For example, in a noisy environment or when a headset is not available, a user can take advantage of having films subtitled. There are data available to support this claim. According to [12], *"57 % of computer users in the US ranging from 18 to 64 years old (74.2 million) are likely to benefit from the use of accessible technology due to disabilities and impairments that may impact computer use"*.

One of the main challenges of dealing with accessibility requirements is that the needs of users vary a lot depending on the type of disability. This makes it more difficult to propose holistic approaches that tackle more than a single profile of disability.

2.3 Game Development: Tools And Approaches

Game development tools and approaches have evolved as a response to the diversification of gaming. Currently there are a wide range of tools for all sorts of games and audiences, allowing not only professionals but also people without a lot of resources or a deep technical background to create their own games. For example, simple tools like *Scratch* [13] or *Game Maker* [15] were designed to be used by students, as a way to learn programming through game development in a highly visual, user-friendly environment. Other tools, like *GameSalad* or *Unity*, support enthusiastic developers to create their own games with a high level of autonomy and independence. There are even tools that enthusiastic teachers can use to create simple educational games for their students.

These scenarios have little in common with the development of AAA commercial games that cost millions of dollars, involve teams of hundreds of developers and take years to create, which are supported by professional toolkits that are much more complex (e.g. *Unreal Engine*). But in none of these cases game development is a straightforward activity. And in none of them accessibility is the main concern for the creator of the game. For that reason, these tools should facilitate dealing with player diversity in general and accessibility in particular as much as possible. However, there are few tools in the market that integrate accessibility features, and tend to be experimental rather than mainstream. For example, in [20] a framework that supports dynamic game adaptation for people with cognitive and physical disabilities is described. In [16] a framework for authoring interactive narrative-based audio only adventure games is presented.

2.4 Approaches to Game Accessibility

A growing body of research is exploring how to make games more accessible [21]. Advocators and communities of disabled users are producing guidelines that provide orientation and raise awareness among game developers [9, 23]. Accessible games have also been developed for different types of disabilities, integrating novel interaction techniques. For example, in [8] an action game developed for blind gamers is described. [14]. In [17] speech and humming interfaces are used to make a Tetris game accessible for people with limited mobility of their hands. In other cases, existing games are adapted for a specific type of disability. For example, in [1] the adaptation of the popular *RockBand* game for blind users is described. Another example is *Half Life 2*, that was fully captioned after the prequel (*Half Life*) was criticized for providing essential information to complete the game only through audio [10]. However, the solutions proposed are usually focused on a particular game and one or two types of disability, which makes it hard to scale the solutions proposed.

3. APPROACH AND UNIQUENESS

We have conducted three different experiments to answer our research questions. In these experiments we explore different aspects of gaming that contribute to diversity:

- *Player diversity*: We consider players with different accessibility requirements and also with different gaming habits (in one of the experiments).
- *Platform diversity*: We have explored both desktop and mobile games.
- *Application field*: In two experiments we considered educational games, where in the third experiment we addressed purely recreational games.
- *Development approach*: We explored two different ways of creating games. In the first two studies we used a high-level authoring tool for point-and-click educational games. In the third study we created a framework for mobile accessible games. In the first case the software created targets game authors with a low technical profile (e.g. educators) while the second case targets game programmers.

Figure 1 provides an overview of the three studies and how they cover the aforementioned four aspects.

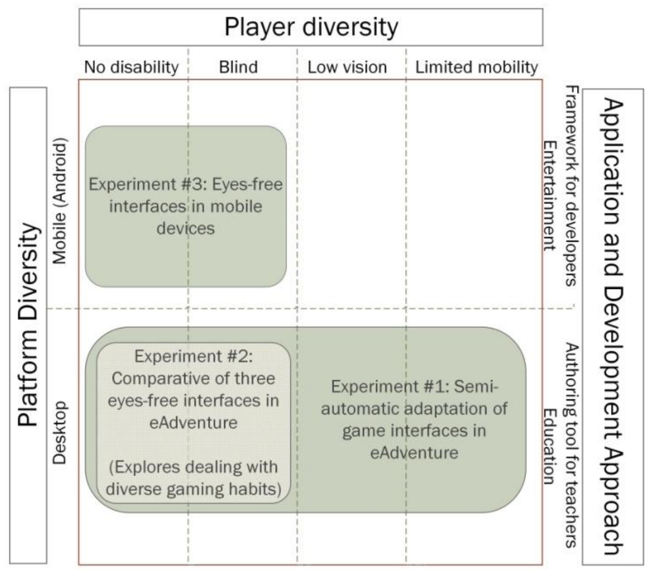

Figure 1. Scheme with the three experiments conducted and how they cover diversity of players, game development approaches, and platforms.

3.1 High-Level Approach: A Serious Games Authoring Tool

Our first approach was centered on the eAdventure game authoring tool [4, 18]. This tool is oriented to educators, allowing them to create their own educational games. The tool interface is simple, with a high level of abstraction as programming is completely hidden from the end user. The strategy used in eAdventure to reduce the complexity of the tool is to narrow the type of games that can be produced to a limited number of genres. As opposed to more complex tools, like *Unity*, which allows development of a wide range of games, eAdventure allows development of only 2D, single player, adventure games.

Besides, many aspects of the games are preconfigured, although the user can perform some tweaks. This happens also with the interaction settings. By default, interaction is *point-and-click*, and these are the controls used:

- Mouse movements to explore the scene. When an interactive element is found, visual feedback is provided (the mouse pointer changes and a brief text is displayed).
- Mouse left button clicks: trigger interactions with some elements or make the player's character move to the given location.
- Mouse right button clicks over interactive elements: display a contextual menu with available actions, if more than one.

3.1.1 Experiment #1: Diverse disability profiles

Three alternative interaction modules that overrode the default point-and-click interaction were developed for eAdventure. These modules targeted three profiles of players: 1) screen reader users (i.e. blind), 2) players with limited vision that use high contrast settings, and 3) players with motor impairments in hands that use voice recognition software.

Both blind users and users with limited mobility experience problems operating *point-and-click* devices, either due to the lack of missing feedback or to the lack of fine motor control. The adapted interfaces allowed blind users to introduce commands using the keyboard, while users with a motor disability use speech-recognition to achieve the same goal.

In both cases, players formulate short commands in natural language: (e.g. "grab the notebook" or "talk to the character"). An interpreter reads the commands, executes them if they pass a syntactic and semantic validation, and provides suitable feedback using the appropriate channel (auditory for blind users through a built-in text-to-speech engine, and text for users with limited mobility).

Command processing is driven by a grammar that defines valid commands, combined with a list of synonyms for relevant verbs (actions) and nouns (interactive elements) that includes built-in synonyms for common words (e.g. "use", "grab", "talk") and synonyms specified by the game author for each game element. The grammar is automatically generated from each game description, based on the game actions defined for each of the interactive elements available in each game scenario. An additional set of game-independent vocabulary provides access to always-available interactions such as opening menus, skipping dialogue lines, or exiting the game altogether.

Major barriers for low vision users are related to having interactive elements that blend into the background or elements and fragments of text that are too small. Additionally, color-blindness can result in nominally different colors blending into each other, and is especially problematic when color is used to encode important attributes.

We use a number of strategies to address these barriers. First, text size and small game elements are significantly enlarged. Second, a special rendering mode is used to improve the contrast of interactive elements over game-scenario backgrounds, applying a strategy similar to the high-contrast mode found in Terraformers [22]. We increase the luminosity of interactive elements using a light green filter, and add a dark purple filter to all other areas, decreasing their brightness. Font sizes and colors used for cursors, buttons and menus are also adapted automatically.

The system was built to be as easy to configure as possible. Game authors were only required to set up a few parameters and some additional descriptions for blind users. Optionally, and depending on the game, the author must also provide alternative versions of the art resources used to adapt the interface for users with low vision. The eAdventure accessibility module, using these settings, adapted the interfaces depending on the requirements of the player.

These interfaces were evaluated by creating a serious game: *My first day at work* (Figure 2). In this game, the player adopts the role of a person with a disability that is hired by a company. To complete the game, the player has to fulfill several assignments that allow him or her to get familiarized with colleagues and equipment. The game was developed in collaboration with experts in usability and accessibility from *Technosite* (ONCE group) and it was set up with the three interfaces described above.

Figure 2. Snapshot of the game "My First Day at Work".

3.1.2 Experiment #2: Diverse player preferences

A second experiment was conducted to explore game interfaces optimized taking into account the gaming habits of the user. As opposed to recreational gaming, in education the player does not choose to play, as it is one of the activities defined by the teacher. In this regard, it is necessary to produce educational games that appeal to avid gamers and also to students with little interest in games.

This study targeted profiles of players sharing a common disability (blindness) but with different gaming experience. Three interfaces were developed. The first interface was similar to Web interaction, allowing users to browse through the elements and GUI controls with the arrow keys and use an action key (e.g. Enter) to trigger interactions. The second interface was the most innovative, being a 3D sonar that helped users in locating the elements with the mouse. The third interface allowed interaction through short text commands [19].

3.2 Experiment #3: Android Framework For Mobile Accessible Games

As a second approach, a framework was developed to facilitate creation of 2D accessible games for screen reader users in mobile devices. Android was chosen as the application platform, as at the time of the start of the project it was a less accessible platform than its competitor, iOS. The outcome was a number of libraries and classes that could be integrated into Android game development projects. This framework is available for download from its Google Code repository [3].

Using this framework, four accessible games were produced. Three of them are available at Google Play. Compared to the previous approaches that focused on the eAdventure platform, this solution has advantages and disadvantages. On the one hand, it allows for developing games of different types, as adopting a low level strategy adds flexibility and scalability. While in the previous approach only point-and-click adventure games could be created, with this approach a minesweeper, a point-and-shoot game, a snake-like game and an interactive fiction game were developed. Besides, this approach is less platform dependent, as it could be reused in any Android project while interfaces described in section 3.1 could only be used within the eAdventure authoring tool. However, the cost of producing games increases as the setup of the interfaces required coding, which is a significant drawback. Besides, the software does not provide explicit guidance on how to make use of the accessibility features, which are just provided in the aim of being useful and its eventual use is left at the solely discretion of the developer.

4. RESULTS AND CONTRIBUTIONS

End-user evaluation was conducted in the three studies. An overview of the results obtained is provided in section 4.1. This helps us to answer the first research question: "Can (semi-) automatically generated interfaces deliver pleasant game experiences for a diverse target audience?". A discussion of the impact that dealing with player diversity had on the game author is also provided in section 4.2. These results will help us answer research question 2: "To what extent can game development software help reduce the cost of dealing with diversity?". Finally in section 4.3 we discuss how this project has contributed to the field of gaming in particular and Human-Computer Interaction in general.

4.1 End-User Evaluation

In the three studies an end-user evaluation session was conducted. In the first study (multiple disabilities, eAdventure platform) 9 users with different disabilities (3 with low vision, 3 blind, 3 with limited mobility) were recruited and played the game "My First Day at Work" in a controlled environment for 60 minutes. 5 users with no disability were also recruited as a control group.

In the second study (eyes-free interfaces, eAdventure), four middle-aged blind users with different gaming habits were recruited. They played three mini-games that were setup each with a different interface in a controlled environment.

In the third study (eyes-free interfaces, mobile games) evaluation is being conducted online. Three of the four games developed were published on the Google Play market on June 2012. A Likert end-user questionnaire was integrated in each game and responses are being collected. By April 2013 70 responses have been collected. 30 of the users reported to be legally blind; 8 reported to have low vision and 32 reported to have no visual disability.

All users recruited in the first and second studies were volunteers, which may have introduced noise in data collected. Recruitment may also have been biased study 3 as researchers have no means to verify the disabilities reported by the users.

4.1.1 eAdventure - My First Day at Work

In this study the end-user questionnaire had 9 Likert 4-point items. These items were oriented to rate aspects of the gameplay experience (e.g. Was it fun? Was it frustrating?) and the usability of some aspects of the game (Was sufficient guidance provided? Were texts appropriate? etc.). 7 of the 9 items showed strong correlation (Cronbach's alpha test: 0.905) and were added up to generate a scale ranging from 7 to 28. Results were compared across types of disabilities (see Figure 3). The group of users with no disability was used as a control group.

Responses collected from blind users and users with low vision were similar to the control group (medians: 20.00, 21.00 and 23.00 respectively; means: 20.00±5.66, 20.67±6.51 and 21.20±3.42). In contrast, users with reduced mobility scored significantly lower (Median: 17.00, Mean: 19.33±6.81). This difference is attributed to the speech recognition software used, which had produced unexpectedly low accuracy rates during the evaluation session, making users frustrated. Blind users and users with low vision also found barriers while playing, but they were able to overcome them and they had a minor impact on their play experience.

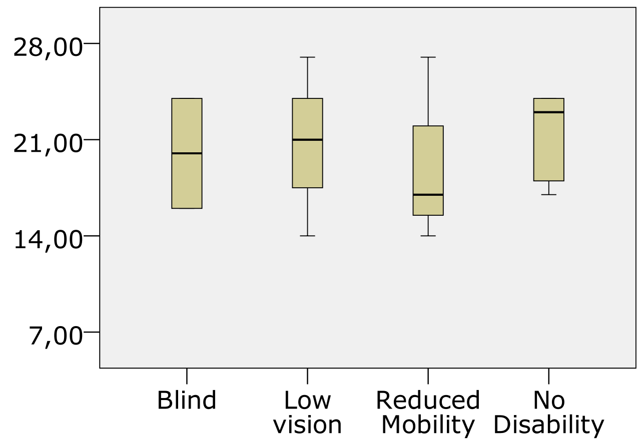

Figure 3. Boxplot with results of the end-user questionnaire for the interfaces developed in eAdventure for users with different disabilities. Vertical lines show min and max values. Boxes represent results between percentiles 25 and 75. Median is marked inside each box.

4.1.2 eAdventure - Eyes-free interfaces

In the second study, blind users were simply asked to rate using a 7-point Likert format the easiness of use and fun provided by the three game interfaces (keyboard navigation, sonar and conversational). They were also asked to elaborate on their decisions. For the users, the easiest interface was the first, but it was also the less fun. Surprisingly, they considered the sonar interface the most fun.

Table 1. Summary of data collected for each of the eyes-free game interfaces developed in eAdventure. #1: Keyboard navigation; #2: Sonar; #3: Conversational (commands)

	#1	#2	#3
No. Users completed the game	4/4 (100%)	3/4 (75%)	2/2 (100%)
Completion time (min:sec)	Mean: 3:21 Min: 2:54 Max: 3:48	Mean: 6:54 Min: 6:17 Max: 7:21	Mean: 4:26 Min: 4:19 Max: 4:34
Easiness of use (*)	**Median: 7/7**	Median: 5/7	Median: 5.25/7
Fun (*)	Median: 5/7	**Median: 6/7**	Median:5.5/7
(*) Results from a 7-point Likert questionnaire			

An interesting finding was that users that were not used to play digital games tended to prefer interface #1, probably because it resembles navigation via the Web, which is a sort of interaction they are familiar with. In contrast, users that were more used to playing digital games preferred the sonar, which was the hardest to control (see rates and avg. completion times in Table 1) and very unfamiliar to all of them. This suggests there is really a diversity of preferences regarding gaming in the population of blind users, although further research with a higher sample must be conducted to contrast the findings.

4.1.3 Eyes-free games on Android

The end-user questionnaire used to evaluate the eyes-free mobile games had 6 5-point Likert items. Items were oriented to evaluate the game-play experience (e.g. "Was the game engaging?" "How fun was it to play the game?", etc.) and the quality of different aspects of the game (e.g. "rate the accessibility of the controls", "rate the feedback provided by the game", etc.). Items were summed up to build a scale ranging from 6 to 30 (Cronbach's alpha: 0.903). Results are provided in Figure 4. Results are mostly positive in both blind and sighted users (Medians: 20.00, 16.5 respectively; Means: 21.15±4.92, 17.60±7.41), although they are higher for blind users. Results for sighted users show also more dispersion. The difference can be attributed to the design of the games that were developed thinking of blind users as the target population.

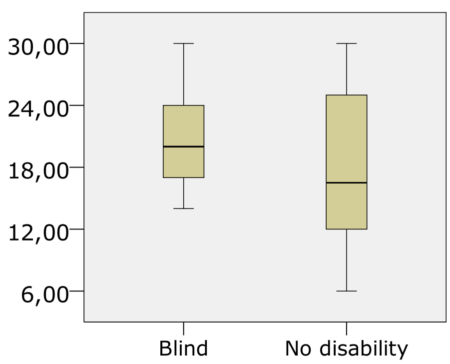

Figure 4. Boxplot with results of end-user questionnaires for the three Android eyes-free games developed. Vertical lines show min and max values. Boxes represent results between percentiles 25 and 75. Median is marked inside each box.

4.2 Analysis of the Cost.

The actual impact that dealing with diversity had on the game author (in terms of additional effort and cost) cannot be easily quantified. However, in Table 2 we provide some data on additional effort required during the process of creating the game "My First Day at Work" to support discussion.

To enable data collection, the game was first developed for users with no disabilities and in a second stage it was adapted for people with disabilities using the semi-automatic system built into eAdventure. This allows measuring how many additional game elements had to be manually produced (and how complex they are) as an indicator of the total effort dedicated to the task. As Table 2 reports, most of the aspects of the game that experienced a significant increase were additional text descriptions and synonyms produced to feed the natural language processing unit and the audio feedback system for blind users and users with reduced mobility. Fortunately, providing alternative pieces of text is inexpensive. It was also required to develop alternative tutorials for blind users and users with reduced mobility. Additional versions of some art resources were also produced for situations where the quality of the scenes rendered in high contrast mode was insufficient. These processes are more expensive, but they resulted only in a small cost increase.

4.3 Discussion of the Contributions

Results outlined in this project are promising and motivate further exploration of the possibilities that game development software can provide to simplify the creation of games that can be enjoyed by a wider audience. Although developed game interfaces are not free of barriers, the evaluation of the player experience and overall usability justifies further research in this line. Results also allows us to answer affirmatively to RQ#1, as it seems feasible to deliver good quality player experiences with this kind of interfaces. Regarding RQ #2, the analysis of the extra cost needed to introduce accessibility in one of the games shows the potential for cost reduction provided by this approach.

Table 2. Analysis of the effort needed by the game author to make the game "My First Day at Work" accessible using eAdventure. Effort is estimated through calculation of additional elements created.

Relative Cost	B=Before	A=After	I=Increase (I=A-B)	% Increase (%=I/B·100)
Game text (dialogues, conversations, descriptions of elements, etc.) for audio descriptions (No. of words)				
Low↓	6341	10208	3867	60.98%
Synonyms for the natural language input processing module				
Low↓	188	698	510	271.28%
Size of the tutorials implemented for blind users and users with limited mobility				
Medium↓	9220	10172	952	10.32%
Number of alternative art resources developed for the low vision mode				
High↑	638	700	62	9.71%

The three studies that constitute the body of this project have provided some insight on player diversity and accessibility that may be of interest for future research on gaming and HCI. The project has proposed game interface models that can be used to deal with a diverse target audience. In this project, diversity has been considered in three factors: player capabilities (i.e. disability), player gaming habits and target device (desktop Vs mobile). The interfaces proposed could help other researchers and practitioners in optimizing the gameplay experience under these conditions.

This project has also produced outcomes in the form of free, open source software products that the community of users with disabilities can take advantage of, including:

- Game development software that helps to produce games that are more accessible. Two different products were produced: an authoring tool that can be used in small to medium developments, and an Android game framework that can be used by developers in mobile platforms.
- A desktop game "My first day at work" that can be played by users with disabilities.
- Four games that can be played by blind and sighted users on the Android mobile platform (developed by two undergraduate students under our supervision).

Ultimately, we expect this work to raise awareness among other developers of the importance of making game interfaces that are optimized for diverse players.

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