Computer Science and Information Systems 0(0):1–7 DOI: N/A

Towards a Low Cost Adaptation of Educational Games for People with Disabilities

Javier Torrente[1]*, Ángel del Blanco[1], Ángel Serrano-Laguna[1], José Ángel Vallejo-Pinto[2], Pablo Moreno-Ger[1], Baltasar Fernández-Manjón[1]

* *Corresponding author*
[1] Department of Software Engineering and Artificial Intelligence, Complutense University of Madrid.
C/ Profesor José García Santesmases sn, 28040 Madrid (Spain)
{jtorrente, angel.dba, angel.serrano, pablom, balta}@fdi.ucm.es
[2] Department of Computer Science, University of Oviedo. Asturias, Spain
vallejo@uniovi.es

Abstract. In this paper we analyze how to increase the level of accessibility in videogames by adding support for it in game authoring software. This approach can reduce the effort required to make a game accessible for people with disabilities, resulting in significant savings. A case study is presented to support the approach based on the eAdventure educational game authoring platform, which allows semi-automatic adaptation of the games. The game, "My First Day At Work", was made accessible for students with different disability profiles, mainly blindness, low vision and limited mobility, although hearing and cognitive disabilities are also considered. Results show that the effort needed to make the games accessible is moderate in comparison to the total effort dedicated to game development. Although the specific solutions proposed are optimized for educational games, they could be generalized to other game frameworks and purposes (e.g. entertainment, advertising, etc.).

Keywords: accessibility; educational games; serious games; universal design.

1. Introduction

Education is a universal right. This implies the need of considering accessibility as a high priority requirement whenever new technologies are brought into the educational process. Otherwise we may be threatening the equality of opportunities for all students. This should be the case of educational games (a.k.a. serious games), which are rapidly gaining acceptance and will probably become a relevant educational tool for enthusiastic teachers in the next few years [1, 2]. But current level of accessibility in videogames (both commercial and educational) is still relatively low compared to other kind of technologies and digital static contents like the web [3–5].

One of the main arguments to explain the little attention that accessibility receives in games is that it means an extra burden for the developers and an expense increase factor. Firstly, the game increases in design complexity. Games are intricate, heterogeneous and highly interactive applications [6] that provide unique experiences depending on who is playing and what title is being played [7]. Designing an engaging, appealing and meaningful game for a wide number of users is an art that requires loads of expertise and creativity. When designers have also to cope with the special needs of users with disabilities the difficulty of the job increases substantially. And secondly, developers are faced with extra implementation challenges. Dealing with accessibility usually requires integrating (or even developing) complex and expensive technologies, such as text-to-speech or voice processing modules. And it may even require producing special hardware (e.g. adapted game controllers) [8].

All these overheads may be affordable only for large entertainment game development projects, and even then most entertainment games tend to ignore accessibility concerns. Educational game development should be driven by austerity and cost optimization to achieve wider adoption [9], an axiom that clashes with increasing budgets to accommodate accessibility. To avoid leaving accessibility concerns out of these projects, making accessible game-based educational content should be as seamless and cost-effective as possible. Our proposal is to increase the support that game authoring software provides to the author to make accessible games resulting in a reduction of the effort required. This involves enhancing game tools with new components that adapt the game to suit the needs of the player with a minimum amount of author input.

However, automatic adaptation of games is a serious challenge [10], especially if the goal of the adaptation is to meet the special needs of people with disabilities. Gameplay experience is so dependent on the design of the game that general purpose approaches are hard to envision. For that reason, this paper narrows the scope to a particular game authoring platform, eAdventure, that is optimized for the development of 2D *point-and-click* games [11]. Through a case study we discuss to what extent it was possible to reduce the effort (and thence the cost) needed to make a game accessible.

This paper is structured as follows: in section 2 we provide an overview of several initiatives aimed at improving the accessibility of digital games. In section 3 we discuss the adaptations required to make a game accessible for different profiles of disability. In section 4 we briefly describe the approach followed to introduce accessibility in the eAdventure game editor. In section 5 we describe, as case study, an accessible game developed using the prototype described in the previous section. In section 6 we discuss the usability achieved with the adaptations performed on the game. Section 7 discusses the effectiveness of the approach in terms of cost and effort reduction. Finally, section 8 draws conclusions and outlines future lines of research.

2. Related Work

Although research on game accessibility has not received as much attention as other fields, there are several approaches that deserve recognition. In this section we provide an overview of how different authors have adapted videogames for people with disabilities (section 2.1), and other comprehensive proposals to add accessibility to a wide range of games (section 2.2), whose spirit is more similar to our approach. We recommend reading works by Yuan and Westin for a detailed literature review [4, 5].

2.1. Ad-hoc approaches

Making games accessible is a very complex issue that requires taking different actions across multiple aspects of the game, like producing adapted versions of the art resources, integrating universal design principles in the game design, or extending the functionality of the underlying game technology (e.g. a game engine) [12]. The process of adapting a game is highly dependent on the game genre and the specific types of disabilities being considered [13]. Moreover, in many cases adaptations performed for a game do not adequately scale to other games of the same genre or similar nature. Thus, accessibility has been usually addressed game by game.

Different works have explored how to design and implement games to accommodate the needs of players with one or more disabilities [14–16]. In these situations, accessibility is considered *a priori*. Considering accessibility *a priori* is frequently advised by experts in the field [13]. In early stages of development it is easier to modify the game design (e.g. dialogues, technology, puzzles, interface design, etc.) or the underlying technology (e.g. game engine, text-to-speech support, etc.), which facilitates personalizing the user experience to the needs of players with disabilities. As a drawback, *a priori* accessibility may complicate development and increase the costs, depending on the case, as it requires concurrent development of different game versions (or branches). For that reason, accessibility is not considered since the beginning very often. To address this shortcoming several works have explored the adaptation of a specific title to meet the needs of a particular user profile [17–19] *a posteriori*, once a fully-functional prototype is available. However, these approaches rarely address multiple disabilities (e.g. blindness, deafness, low vision, etc.) at the same time since making modifications in the core of the game is much more complicated once development has been completed.

Ad-hoc solutions are necessary to increase understanding on what is needed to make playful experiences that are accessible to everyone, as they allow approaching the problem in a stepwise way and from multiple perspectives, exploring alternative solutions for a particular disability and/or game genres at a time. However, it is necessary to build general models that can be widely applied to accessible game development.

2.2. General approaches

Building on some of the ad-hoc solutions above presented, other approaches have adopted a more general and holistic perspective, proposing guidelines, frameworks and methodologies that consider the needs of different user profiles that could also be applied to different types of games [4, 8, 20–22].

One of the first initiatives with a broad scope was the game accessibility guidelines produced by the Special Interest Group on accessibility of the International Game Developers Association [8]. In this white paper published on 2004, a set of practical recommendations were proposed to avoid most of the common accessibility barriers that were identified in popular games of the time. Building upon this document, the MediaLT group published a more detailed set of recommendations and guidelines grouped by profiles of disability [21]. Recently, a new set of good practices has been published targeting developers, which provides examples of how recent games have solved some of the problems. This set of good practices is structured in levels of detail (basic, intermediate and advanced) to support a stepwise approach to the problem, which resembles to the accessibility conformance levels proposed by the W3C consortium [23]. However, game accessibility guidelines are still far from being as mature, agreed-upon and widely adopted as the W3C recommendations are. First, many W3C recommendations have the consideration of standard, being their use mandatory in several environments. The use of game accessibility guidelines has not been explicitly supported by any standardization body yet. Second, there are numerous support tools available for the W3C recommendations, dedicated to evaluate the level of compliance of websites, and also to support content creation that complies with the W3C. In contrast, there is nothing equivalent for game accessibility guidelines.

With a more academic tone, in [20] the authors propose Unified Design of Universally Accessible Games (UDUAG), a methodology for designing universally accessible games where game tasks are devised without considering a specific modality or interaction device. In further design phases, alternative interaction methods are designed for each task depending on the needs of the target audience. Therefore the game design is extensible, facilitating the subsequent inclusion of accessibility features to cater for the needs of other users. The UDUAG methodology has been used in the development of several accessible games, like UA Chess [24] or Access Invaders [25].

The drawback of these general approaches is that most of them do not provide a reference implementation that could facilitate the work of the developer. One exception is a system called Blindstation [26], which separates interface and logic components to facilitate interoperability with different input/output devices. Other technology developed with a similar purpose is described in [27]: an audio-only 3D game engine which provides a software architecture to make immersive games for people with visual disabilities.

3. Strategies for Adapting Games for Players with Disabilities

Regarding the type of disability, the number of accessible games is not distributed evenly, as not all the needs require the same effort to be accommodated. In this section we provide a concise description of how game accessibility has been approached for different profiles of disabilities.

Classification of disabilities is a controversial topic where the terms are used differently depending on the context and who is speaking. For the scope of this paper, we consider the next types of disabilities, based on the kind of adaptations required in each case:

- *Blindness:* As blind users we refer to people that need the aid of screen reading software (e.g. JAWS) to use a computer.
- *Low vision*: Users with low vision are those that usually need screen and text magnification tools and use of a high contrast color scheme.
- *Motor disability*: Users that need to use voice recognition software to interact with a computer due to reduced or lack of mobility in their hands.
- *Hearing disability*: Users that require replacing or complementing audio return of information with visual stimuli.

- *Cognitive disability*: Users that require adapting the pace, the complexity of the story, puzzles, dialogues, instructions, levels or mechanics.

3.1. Blindness

The blind are among the profiles of disabled users that have gathered more attention. For example, the Audio Games community provides lots of titles of audio-based games designed for users with a visual disability [28]. Some of the games, like *Papa Sangre* [29], even avoid incorporating graphical support. The games that blind gamers can play are usually more varied than for other users with disabilities, including racing games, FPS, Role-Playing Games (RPG), Puzzle, Arcade or Music games. Most of the games available to blind users are oriented to leisure, but occasionally their use as educational tools has also been explored. This is the case, for example, of the game described in [30, 31], which used a virtual reality game with haptic feedback to improve navigational skills of blind people.

Barriers found by blind players are usually related to perceiving feedback provided by the game. For that reason, adaptations are usually related to the replacement of visual stimuli with audio [28, 32], haptic feedback in several forms [33, 34], or more often a combination of both [14, 18, 35, 36]. Audio-based techniques are the most varied, being easy to find different strategies in the literature, like using *auditory icons* and *earcons* to associate information to sound. The main difference between the two is that, while *auditory icons* are recognizable and designed to resemble to real sounds, *earcons* are structured musical messages [37]. Both techniques have been applied in several games like *Tim's Journey* [28] or *Os & Xs*. Other games use more sophisticated audio solutions, like spatial or 3D sound [38].

In many cases blind users may also find barriers in providing input, for example if the game is controlled with the mouse. In these cases, it is also necessary to provide an alternative modality, like allowing to control the game using a keyboard (which is the most common approach) [30], or special hardware [15].

3.2. Low vision and Color Blindness

Users with low vision usually encounter problems when the objects or the font sizes are too small in the game [8]. Using color codes to convey information is also an issue, especially for users with color blindness. Another important barrier is having low contrast causing interactive elements or game objects blend in the background, or if visually tracking a moving element is essential to advance in the game at any point [39].

To address these issues, three types of adaptations are the most frequent. Firstly, the accessible game provides functionality to increase the size of the font and the elements, and/or provide a screen magnifier to enlarge parts of the screen. Secondly, the game provides alternative ways to convey information that do not depend only on color (e.g. using also symbols) or at least offers several color schemes that the player can choose from. Finally, some games provide a high contrast mode that affects the rendering pipeline [22]. The typical behavior is to apply a black-and-white filter to make easier to distinguish important elements from the background and enhance the contrast of the text over the background, like in the PowerUp game [39]. Another alternative is to alter the luminosity of the elements, for example having darker characters and brighter backgrounds and vice versa. This can be achieved by producing alternative versions of the art resources when the game is created or by applying filters at runtime. This technique is used, for example, in the Terraformers game [16].

3.3. Limited Mobility

Users with limited mobility in the hands usually have trouble playing with standard game controllers (e.g. joysticks or gamepads). This problem can be addressed with *software* or *hardware* solutions. Software approaches rely on speech recognition programs that convert voice commands into game actions. *Hardware* approaches focus on producing new game controllers suited for people with disabilities, or adapting standard gamepads. Special input devices available are varied, having for example brain controllers [40], tongue controllers [41] or eye trackers [42]. However, switches that allow interaction with simple taps of the hand, head or other parts of the body, are probably the most common [25].

Users with reduced mobility would also require tweaking the game to limit the amount of input that is needed to play it. Even if the user has an adapted controller or input mechanism, probably she will need a slower game pace to have enough time to make choices and respond to game events. For example, in [43] a classic Tetris game is made accessible for people with a motor disability using two different interfaces: one based on humming and other based on pure speech. In [44] a Sudoku is played using one of two alternatives to control the game: one using either speech or a single switch/button system, and the other making use of a scanning system that changes the focused object automatically at a predefined time rate and following an order that is known to the user. This allows users interact with the game using only one control (e.g. a switch).

3.4. Hearing disability

Barriers experienced by users with a hearing disability arise when effects, essential information or parts of the plot are conveyed only using audio. This kind of barriers could be solved replacing audio with visual information. The most common approach is to replace the audio information with text using techniques like subtitling or close captioning [45, 46]. This was the case of the popular Half Life© game, released in 1998 by Valve Studios. The title gathered a lot of criticism from communities of deaf gamers as information required for finishing the game was provided in uncaptioned cut-scenes. Critics had definitely an impact on Valve's, as its sequel, Half Life 2©, was 100% deaf gamer friendly [47].

Even if no essential info is conveyed in audio-only format, gamers with a hearing disability can be in disadvantage, especially in games where fast reaction to stimuli is required (e.g. First Person Shooters). For example, missing gunfire audio cues may result in a deaf gamer being shot [5]. In these cases the most common approach is to replace the audio with visual cues. For instance, GarageGames' Torque Game Engine©

supports, along with closed captioning, displaying a sound radar that visually identifies the direction and intensity of sound sources in the scene [48].

Alternatives to visual conveyance of audio information are less frequent, but can also be found. Two examples are CopyCat and SMILE, two educational games developed for deaf children. CopyCat is a game that recognizes sign language gestures [49], and it was developed to help young deaf children practice American Sign Language (ASL). SMILE was developed to teach science and maths to students with hearing problems [50]. In this case students also use ASL to interact with the game.

3.5. Cognitive disability

Cognitive disabilities are complex and diverse and the number of barriers that these players may encounter is varied and highly dependent on the type of disability, even on the abilities of each individual player [8].

Most common problems for these players are related to the design, content and mechanics of the game. This includes aspects like the complexity of the puzzles the player is challenged with, the language registry used, or not having enough time to decide the next move on the game in response to a given stimuli. Common strategies adopted include reducing time constrains, the amount of stimuli or input [5], and providing alternative difficulty levels [51].

A considerable number of educational games for people with cognitive disabilities of all ages is available in the literature [52–55]. This contrasts to the relatively low number found for students with physical disabilities. Different genres are used, although virtual reality and 3D environments are preferred. For example, in [56] a Web multi-player game is used to foster development of social skills in autistic children. In [57] a drill-and-practice 3D game is used to instruct fire and street safety skills in children with developmental disabilities, showing a positive impact.

4. Coping with Accessibility in the eAdventure Educational Game Platform

eAdventure [58] is a game authoring platform especially oriented to education[1] [59]. Although eAdventure supports the creation of a variety of 2D games, it was originally focused on *point-and-click* conversational adventure games. The genre was initially chosen because it has interesting traits for education, like strong narrative underpinnings and predominance of reflection over action [60–62].

eAdventure has two components (Fig. 1): a game editor used to create the games and a game engine, used to run them. The typical workflow is to create and test the games with the editor, and then use an editor tool to produce a distributable package. This package contains the game engine and all the assets needed to run the game (XML documents describing the game, images, sounds, videos, etc.). The game editor includes features especially devised for education and tries to simplify the game creation process as much as possible.

1 http://e-adventure.e-ucm-es

The universe in eAdventure games is defined by composing 2D elements of different types: characters, items, active areas, and the game scenarios (a.k.a. scenes).

Accessibility was introduced in eAdventure at platform level, which makes the approach more similar to those described in section 2.2. Instead of focusing on making a single game accessible, our goal was to provide other game authors with features that would help them to make more accessible games. Although these features are currently a proof-of-concept, they will be eventually integrated into the official public distribution. Further implementation details can be found on previous publications [11, 63]. These features can facilitate dealing with accessibility, but their use is left to the solely discretion of the game author. Hence there is no guarantee that a game will be accessible if the creator does not take into account the special needs of people with disabilities.

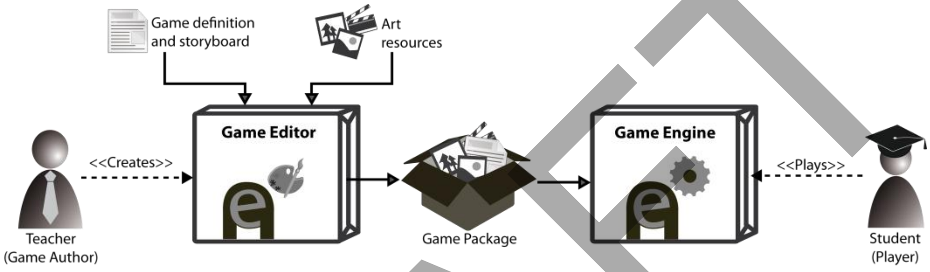

Fig. 1. Diagram of eAdventure applications. The Game editor is used to create the game, while the game engine runs it.

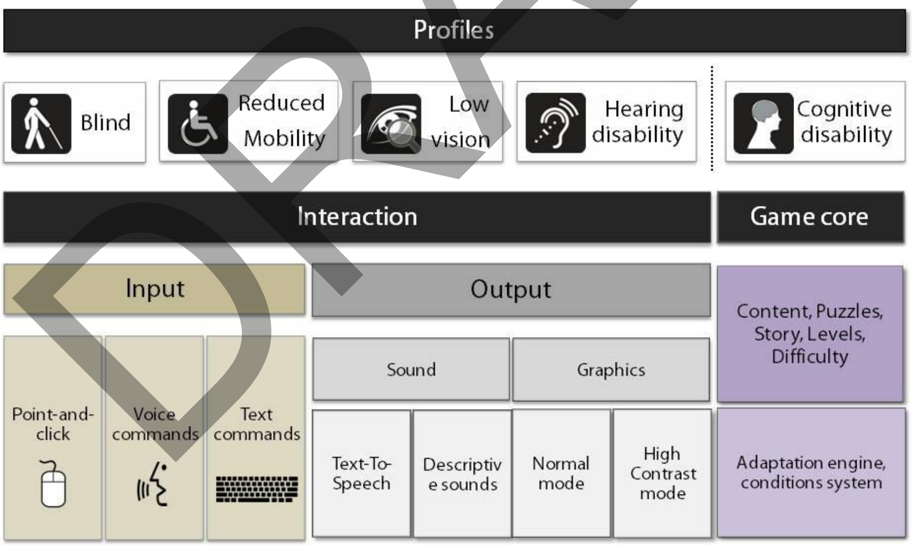

Fig. 2. High level view of the components produced to adapt the interaction for each user profile.

Fig. 2 provides an overview of the features supporting accessibility. For physical disabilities (vision, hearing, limited mobility), which require adapting the modality, alternative input/output mechanisms are provided. The game author can activate these features in the game. After loading, the game displays an accessibility menu where the player can select which features she would like to use.

To deal with cognitive disabilities, game authors can use the eAdventure adaptation engine, built upon a system of flags and variables that facilitates personalization of the game content, puzzles, and difficulty.

Next subsections describe how eAdventure provides game authors with functionality to deal with each type of disability.

4.1. Blindness and Limited Mobility

In eAdventure, both blind users and users with limited mobility encounter barriers that are related to the use of a point-and-click interface, as they are not able to use the mouse. Thus, an alternative interaction mechanism was developed to accommodate their needs, but using different input devices for each profile: blind players introduce the commands using the keyboard, while players with a motor disability use speech.

With this alternative interaction mechanism, the player formulates short commands in natural language to play (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 feedback about the results using the appropriate channel (auditory for the blind user through a built-in text-to-speech engine, text for the user with limited mobility).

Table 1. Example of natural language commands available during gameplay. Examples tagged with (1) would be dynamically defined, as they depend on the specific configuration of each scene. Examples tagged with (2) are common to all scenes and games.

Order	Description
Examine the wall (1)	The game will provide a description of the object "wall", if it exists in the scene.
Go to the door (1)	The student's avatar in the game will move towards the place "door".
Use keys with locker (1)	The game will use the object "keys" on the object "locker"
Name items in the scene (2)	The game will tell the student which items have already been discovered so that he or she can interact with them.
Open options menu (2)	Pause the game and show the options menu.
Describe (the) scene (2)	The game will provide a description of the scene as a hint for the student.

Command processing is driven by a regular grammar that defines valid commands, combined with a list of synonyms for relevant verbs (actions) and nouns (interactive elements) that aggregates built-in synonyms for common words (e.g. "use", "grab", "talk") and synonyms specified by the game author for each game element. This regular grammar is automatically generated from the description of the game, taking the actions defined for the interactive elements available in each game scenario. During game play, the number of actions and interactive elements available in eAdventure games is susceptible to change at any time as they depend on the value of a number of variables that vary dynamically as specified by the game author (this is the mechanism that eAdventure provides to implement the game structure and flow). To deal with this issue the grammar is rebuilt each time an internal variable changes and also each time the scenario is reloaded.

Special rules that remain invariant are added to the dynamically generated ones. These special rules are used to define basic interactions with the game (e.g. open menus, exit game, skip dialogue lines etc.) (see Table 1).

4.2. Low vision

Fig. 3. Above: Adapted visualization of an eAdventure game for people with low vision. High contrast rendering mode is applied darkening the background and highlighting the interactive elements. Below: Standard visualization of the same game scene.

eAdventure does not use color schemes to convey information. Thus major barriers for low vision users are related to having interactive elements that blend into the background or elements and pieces of text that are too small.

To cater for these needs a low vision mode was developed and integrated in the game engine. When this mode is activated, the size of the text and small game elements is increased. Moreover, a special rendering mode is used to improve the contrast of the interactive elements over the background of the game scenarios, applying a strategy similar to Terraformers high-contrast mode [16]. The game engine automatically applies a light green filter to the interactive elements which increases their luminosity and a dark purple filter to decrease the brightness of other areas, making it easier to identify those interactive elements (Fig. 3). Font sizes and colors used for cursors, buttons and menus are also adapted automatically.

4.3. Hearing disability

Users with a hearing disability are probably those who encounter fewer barriers, as eAdventure games are mostly conversational and based on text. To reduce the cost needed to create the games, information is first conveyed with text and, if the budget allows it, audio is added in a secondary stage as a complement. Besides, audio cues are rarely used to convey information, and if used, they are combined with text and they will not require immediate attention as these games are low paced (e.g. there is no need to reply to enemy gunfire).

eAdventure games are not accessible by default for people with a hearing disability, but the platform provides features to support these special needs if that is the author's intention. However, the likelihood of an eAdventure game being accessible for deaf gamers "by accident" (without consideration during the design phase) is rather high.

4.4. Cognitive disability

Cognitive disability is the most complex profile, as the barriers can be present in almost anything related to the insights of the game. Thus the level of accessibility is solely determined by the design of the game, regardless of the characteristics of the implementation platform. However, if the author has the intention to make a game playable by users with a cognitive disability, she can use the eAdventure system of flags and variables to set up conditions in different parts of the game description. These conditions work as "locks" that block parts of the game. The author can define user interactions that trigger special effects that change the value of those flags and variables. These effects work as "keys" that open the locks. The result is a flexible and powerful system that supports the implementation of the storyboard and the flow of the game. It allows unveiling parts of the plot or unblocking elements as the user advances in the game. eAdventure also provides an adaptation engine to customize the game experience for each student by modifying the value of those flags and variables according to certain parameters.

Authors can use these features to support the needs of the students with a cognitive disability. It allows the game author to modify anything related to the game flow, content and mechanics, where these users usually encounter more barriers. For example, the author can use them to create alternative game plots, lessen the difficulty of the puzzles or adapt the game content (e.g. simplify the language used).

5. Case Study: "My First Day at Work"

To evaluate the effectiveness of eAdventure to support game authors in making an accessible game, we conducted a case study in collaboration with Technosite, a company that belongs to the ONCE group (National Organization for the Blind in Spain). A game was developed from scratch, and the process to make it accessible was tracked. The game targeted people with all kind of abilities, although special focus was placed on analyzing the effort required to adapt the game for these three profiles: blindness, limited mobility and low vision.

Fig. 4. Snapshot of the game "My First Day at Work", showing the avatar selection screen. Four characters with different disabilities are ready for their first day in the office.

The outcome is the game "My first day at work" (Fig. 4). In this game, the user plays the role of a person with a disability that starts working in a new company [64]. It is the first day and the player is told to complete several assignments by the supervisor. While fulfilling these tasks, the player will get to know other colleagues and explore the headquarters of the company, learning where the different spaces are and how to get around. After completing the game, the player will be familiar with the new environment, as well as with using basic devices for the job, like the fax, the e-mail, or the photocopy maker. The ultimate goal is to reduce the anxiety that many people with disabilities feel when they are introduced in a new, unfamiliar environment, and facilitate their acclimatization to the new job. The game takes from 20 minutes to one hour to complete, depending on the accessibility modes that are set up and the interface used (it takes longer to complete for blind players as all the information is conveyed through audio).

Next subsections discuss what was the effort needed to implement accessibility for each profile. First, an overview of the tasks that were carried out to adapt the game for each profile is provided. Second, the effort that these tasks involved is estimated. This information will be used later on to draw conclusions about to what extent the process can be automated.

Measuring effort –and ultimately cost– spent developing software is not an easy task, especially for games. There is no standard way to measure how much it costs to make a game, and there is little data publicly available to compare to. For that reason we set our own metrics to determine the additional effort required to make the game accessible. First, we developed the game for the average profile. We measured the 'size' of the elements that compose the game. Internally eAdventure games are defined through a) several XML documents that contain the definition of the objects, scenes and characters, the dialogues and the logic of the game, plus b) the art resources required for drawing each element (images, animations, sounds and/or videos). As an estimation of the size of the games, we measured the length (number of lines) of the XML files and the number of art resources. Then, the game was adapted for the aforementioned disability profiles. We measured again the size of the game and compared to the initial size. It is important to have into account that generally speaking it takes much less time, effort and cost to increase the XML files that describe the game than producing new art resources.

5.1. Blindness and Limited Mobility

Tasks needed to configure the adapted interfaces for blind users and users with limited mobility are very similar, and therefore required a similar effort.

The basic setup of the system was straightforward. Adapted interfaces for these two user profiles were activated using a simple panel for the accessibility features included in the eAdventure editor. As an example, **Fig. 5** shows how these features were activated for the blind user profile.

Two types of text input were needed to configure those modules:

- Input for the natural language processing module (keyboard interaction). This includes providing alternative synonyms for interactions, objects and characters in the game.
- Input for the audio description feature. This includes additional descriptions of the game scenes that are used to convey additional audio information for the blind user when a new scene is entered (e.g. "You are in a laboratory, with a door on your left and a computer on your right").

As Table 2 shows, the total length of the game text increased almost a 61%. Besides, a total of 510 synonyms were provided, which means 271% of the initial number of element names contained in the game.

A preliminary evaluation showed that some users found it difficult to learn to play using these interfaces. This flaw was addressed by designing and implementing two tutorials: one specifically devised for blind users, and another one for users with limited mobility.

It is difficult to estimate the effort needed to implement those tutorials. As a ballpark figure, we have measured the increase in the size of the XML documents that define the game after these tutorials were added, and how many extra art resources were required. These data are provided in Table 3, showing an increase of about 10% of the XML documents and only 1.39% in art resources.

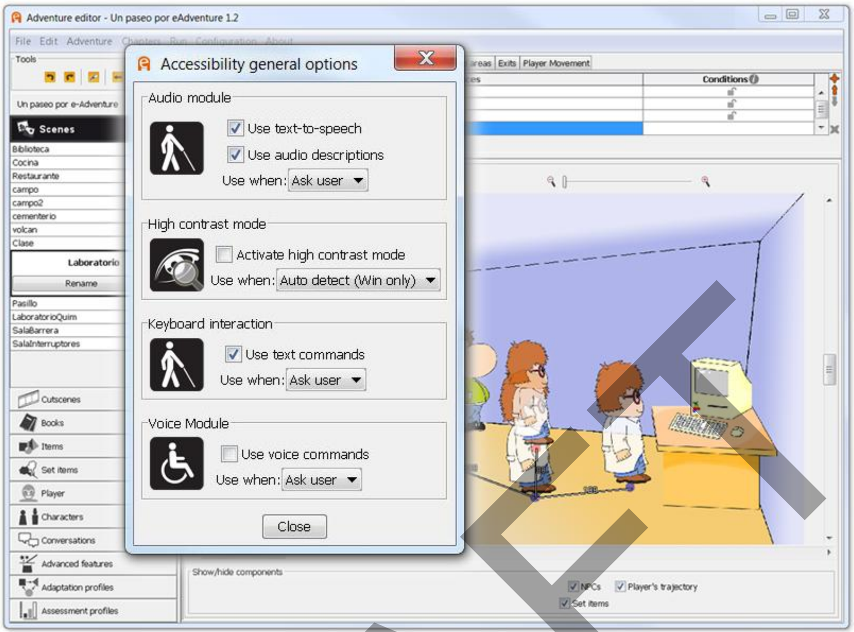

Fig. 5. Accessibility features activation panel. It shows the different accessibility features of the eAdventure editor to make automatic adaptations of the game interface. In this screenshot the options related to the blind user profile are selected. Note: these functionalities are only available in a non-public prototype.

Table 2. Analysis of the effort derived from the configuration of the accessibility modules for blind users and users with limited mobility. Effort is estimated by calculating the increased length of the game texts in number of words (above) and additional synonyms to configure the natural language processing module (below).

Increased game text (No. of words) for audio descriptions				
Concept	B=Before	A=After	I=Increase (I=A-B)	% Increase (%=I/B·100)
Length of conversations and dialogues (Word count)	5712	5712	0	0%
Length of description of objects, characters and scenes (word count)	629	4496	3867	614.79%
Total	**6341**	**10208**	**3867**	**60.98%**

Synonyms for the natural language input processing module				
Concept	B=Before	A=After	I=Increase (I=A-B)	% Increase (%=I/B·100)
No. of synonyms for names of characters and objects	95	314	219	230.53%
No. of synonyms for names of scenes	80	328	248	310%
No. of synonyms for actions with custom names	13	56	43	330.77%
Total	**188**	**698**	**510**	**271.28%**

Table 3. Analysis of the effort derived from additional tweaks and manual adaptations for blind users and users with limited mobility. Effort is estimated by calculating the increase in the game size after implementing the tutorials, considering both the XML documents that describe the game and the number of art resources.

Size of the tutorials implemented for blind users and users with limited mobility				
Concept	B=Before	A=After	I=Increase (I=A-B)	% Increase (%=I/B·100)
Size of the XML documents that describe the game (No. of lines)	9220	10172	952	**10.32%**
Number of art resources	638	647	9	**1.39%**

The overall impact of all these tasks on the cost of the game was not very high. Most of the effort was devoted to writing 4,300 words of additional game text: descriptions, dialogues and synonyms. According to our estimations, game text is produced at an average rate of 500 words per hour, resulting in around 8.5 hours of additional work. Also the game XML files increased in 952 lines. Although it is difficult to translate this value to a number of labor hours, our estimate average production rate using the eAdventure tool is of 300 lines per hour (the XML files are not created manually), making it around 3 hours of work. Finally, some extra effort was dedicated to the production of art resources. This is one of the most expensive tasks in game development, taking around 0.5 hours to make a new resource on average. This results in 4.5 hours of additional work. This makes a total of 16 hours.

5.2. Low Vision

Configuration of the low vision mode was straightforward. The activation of the module was done using the configuration panel described in section 5.1 (see **Fig. 5**). However, the game contained some scenes and objects where text was embedded in images. The system was unable to adapt these images automatically and alternative versions of these art resources had to be provided. As Table 4 shows, this resulted in a 7.57% increase in the art resources produced for the game. As a rough estimation, adapting each art resource from the original took around 0.5 hours,, making around 26.5 hours in total, which is a considerable but affordable extra effort.

Table 4. Analysis of the effort derived from the configuration of the low vision accessibility mode. Effort is calculated by measuring the number of additional art resources that had to be produced.

Number of alternative art resources developed for the low vision mode				
Concept	B=Before	A=After	I=Increase (I=A-B)	% Increase (%=I/B·100)
Number of art resources	647	700	53	**7.57%**

5.3. Hearing and Cognitive Disabilities

In this case, it was not necessary to make any further adaptations to make the game accessible for users with a hearing disability, since from the very beginning all the information was conveyed using text only and audio feedback was added in a second stage. This is the normal process for creating a game using eAdventure. For that reason, this user profile was excluded from the evaluation of the game.

To deal with the needs of users with a cognitive disability a completely different approach was followed. The content and structure of the game was designed from the very beginning to be simple and easy to understand and follow by users with all sort of abilities. These requirements were considered throughout the whole design and implementation process, and resulted in multiple variations of the game design and the addition of game elements that are disperse around the game. Therefore it is not feasible to quantify the effort involved. However, it is reasonable to assume that it is much more complex to adapt the game for this user profile, compared to the others, as it is necessary to produce alternative versions of almost all parts of the game design, which may translate in having almost two different games.

6. Usability

A usability evaluation was conducted involving 12 volunteers with a disability (3 blind users, 4 with low vision, 3 with reduced mobility and 2 with mild cognitive disabilities). Average age of participants was 35.64 (±9.64), with a minimum of 21 and a maximum of 55. Most of the participants were females (11/14; 78.57%). Most of the users were able to complete the game, requiring from 25 to 40 minutes. Each user played alone in a controlled environment under the observation of the researchers. A slot of 60 minutes was allocated for each user regardless of their disability, which was a disadvantage for blind users who required longer to complete the game (they had to listen to long and numerous audio descriptions). As a consequence, 2 blind users were unable to complete it. Users with limited mobility had also problems to complete the game as a consequence of a technical error in the voice recognition system, which ran with an unexpectedly low recognition accuracy.

After playing, a short evaluation survey with 9 Likert 4-point items (e.g. Was it fun?, Was sufficient guidance provided?) was conducted. 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 that estimates the overall player experience and usability of the game. Results from blind users and users with low vision were similar to users with no disability (means: 20.00±5.66, 20.67±6.51 and 21.20±3.42 respectively). In contrast, users with reduced mobility scored significantly lower (Median: 17.00, Mean: 19.33±6.81).

Although users evaluated the game mostly positively, they also identified several flaws that constrained usability. Blind users did not like the voice used for the text-to-speech engine, which was free software, and demanded a better quality Spanish voice. They also requested an improved tutorial and making the commands more intuitive. They also experienced some minor technical problems introducing text commands that were solved immediately after the test. Users with reduced mobility mostly had problems with the accuracy of the voice recognition software used, which was not fine tuned for the Spanish language. Finally, users with low vision pointed out that when they needed to use an external magnification tool some of the context of the game was lost (e.g. occasionally a text string was displayed outside the magnified part of the window).

7. Summary and Discussion

Data discussed in section 5 demonstrate that the effort required to configure the game "My First Day at Work" to be accessible was moderate, at least for physical disabilities. Roughly, two types of additional inputs were required: text, which is "cheap" to produce, and additional art resources, which are expensive but only a few were needed. Furthermore, the level of usability achieved with the architecture developed was satisfactory, although it could be improved. The good balance between effort required and usability achieved suggests that the introduction of accessibility in game authoring platforms is feasible and it can deliver significant reductions in the development cost of accessibility solutions that game authors can benefit from. Not all the user profiles required the same effort and, consequently, the same cost. Eventually, the derived cost of introducing accessibility seems to be tightly linked to the types of adaptations that are required. As a consequence, the level of automation that can be achieved depends on the type of disability. Table 5 provides an overview. Disabilities requiring mostly an adaptation of the interaction (input/output) or modality are prone to be dealt with automatically, as it is usually the case with the physical disabilities (those related to sight, hearing, or mobility) covered in “My First Day at Work”.

Table 5. Summary of adaptations performed for each profile. The table reflects what aspects of the game were affected and the level of automation achieved. Medium and low effort values are considered affordable.

Profile	Aspect	Example of adaptation(s) required	Effort Needed	Potential for Automation
Blind	Interaction / modality	New interface Adapted return of information	Medium-Low	High
Limited mobility	Interaction / modality	New interaction	Medium-Low	High
Low vision	Interface / rendering pipeline	High contrast rendering filters, magnification, alternative images and color schemes	Medium	High
Hearing disability	NONE	NONE	N/A	High
Cognitive disability	Game design and content	Lessened difficulty of puzzles, alternative version of texts	N/A	Low

However, there are cases where more exhaustive adaptations are required, affecting not only the game interface but also the story, the game mechanics, or how the virtual world is constructed. Complex disabilities, like the cognitive ones, usually require adapting a combination of those aspects. It is hard to envision a similar level of automatic support for these disabilities, as they require a deep understanding of the game design and a great dose of creativity. However, this type of adaptations was not analyzed in the case study presented, and therefore empirical data cannot be provided to support this claim.

8. Conclusions and Future Work

Educational games should be as accessible as possible to avoid potential digital divide when they are brought into the classroom. To achieve this it is necessary to reduce the overhead needed to make the games accessible, especially in education where budgets are usually limited. Cost reduction can be reached by integrating accessibility tools in the game development software.

In this paper we have addressed to what extent a game authoring tool can effectively support game developers in making a game accessible. The most important conclusion we have drawn from the study is that the level of automation that can be achieved depends on the type of disability and, especially, on the sort of adaptations that a particular user requires. Adaptations related to the modality, how the user interacts with the game or perceives the game feedback are prone to be automated (e.g. interfaces for blind users and users with reduced mobility). This does not mean that solutions are straightforward, but that current state-of-the-art in technologies like text-to-speech or voice recognition allows building interfaces that can be used by a high number of users. Once these interfaces have been built, they can be reused across different games with little extra work. This kind of solution can help many users.

However, there are cases when these processes cannot be automated, especially for cognitive disabilities. It is still uncertain how to support game authors in dealing with these disabilities, and how to add that support to game authoring software. A possibility is to develop accessibility auditing tools to educate, detect barriers and propose solutions to improve the process of introducing accessibility. Nonetheless, this is just a proposal that we expect to develop further in future research.

It should be noted that these automatic adaptations were designed specifically for educational games, where the tradeoff between cost and accessibility is critical, and accessibility should not be ignored. Entertainment games may also benefit from this type of approach, even though the game industry tends to favor specific developments for each game, due to the rapidly changing technology required to be competitive in that field.

Finally, the solutions proposed were tailored to one particular game authoring tool, eAdventure, which is focused on a very specific type of games. Similar approaches could be applied to other software, since the general spirit is applicable to any game development framework. However, it is still necessary to transfer these ideas to other tools to confirm that the results obtained are scalable.

Acknowledgments. We acknowledge the next organizations that have partially supported this work: the Spanish Ministry of Science and Innovation (grant no. TIN2010-21735-C02-02); the Spanish Ministry of Education, Culture and Sport through the FPU programme (04310/2012); the European Commission, through the Lifelong Learning Programme (project "SEGAN Network of Excellence in Serious Games" - 519332-LLP-1-2011-1-PT-KA3-KA3NW) and the 7th Framework Programme (project

"GALA - Network of Excellence in Serious Games" - FP7-ICT-2009-5-258169); the Complutense University of Madrid (research group number GR35/10-A-921340) and the Regional Government of Madrid (eMadrid Network - S2009/TIC-1650).

References

1. Johnson, L., Adams, S., Cummins, M.: NMC Horizon Report: 2012 Higher Education Edition. Austin, Texas: The New Media Consortium (2012).
2. Johnson, L., Adams Becker, S., Cummins, M., Estrada, V., Freeman, A., Ludgate, H.: NMC Horizon Report: 2013 Higher Education Edition. , Austin, Texas, USA (2013).
3. Bierre, K., Chetwynd, J., Ellis, B., Hinn, D.M., Ludi, S., Westin, T.: Game Not Over: Accessibility Issues in Video Games. 11th International Conference on Human-Computer Interaction (HCII'05). Lawrence Erlbaum Associates, Inc (2005).
4. Westin, T., Bierre, K., Gramenos, D., Hinn, M.: Advances in Game Accessibility from 2005 to 2010. Universal Access in HCI, Part II, HCII 2011. LNCS 6766, 400–409 (2011).
5. Yuan, B., Folmer, E., Harris, F.C.: Game accessibility: a survey. Universal Access in the Information Society. 10, 81–100 (2011).
6. Gee, J.: Good Video Games and Good Learning: Collected Essays on Video Games, Learning and Literacy (New Literacies and Digital Epistemologies). {Peter Lang Publishing} (2007).
7. Egenfeldt-Nielsen, S.: Exploration in computer games-A new starting point. Digra, Level up 2003 Electronic Conference. (2003).
8. Bierre, K., Hinn, M., Martin, T., McIntosh, M., Snider, T., Stone, K., Westin, T.: Accessibility in Games: Motivations and Approaches. (2004).
9. F A S: Summit on Educational Games: Harnessing the power of video games for learning. (2006).
10. Robin, H.: The case for dynamic difficulty adjustment in games. ACE '05 Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology. pp. 429–433. ACM, Valencia, Spain (2005).
11. Torrente, J., Del Blanco, Á., Moreno-Ger, P., Martínez-Ortiz, I., Fernández-Manjón, B.: Implementing Accessibility in Educational Videogames with <e-Adventure>. First ACM international workshop on Multimedia technologies for distance learning - MTDL '09. pp. 55–67. ACM Press, Beijing, China (2009).
12. Ossmann, R., Archambault, D., Miesenberger, K.: Accessibility Issues in Game-Like Interfaces. In: Miesenberger, K., Klaus, J., Zagler, W., and Karshmer, A. (eds.) Computers Helping People with Special Needs: 11th International Conference, ICCHP 2008, Linz, Austria, July 9-11. pp. 601–604. Springer-Verlag, LNCS 5105 (2008).
13. Grammenos, D., Savidis, A., Stephanidis, C.: Unified Design of Universally Accessible Games. In: Stephanidis, C. (ed.) 4th International Conference on Universal Access in Human-Computer Interaction, UAHCI 2007 Held as Part of HCI International 2007 Beijing, China, July 22-27, 2007 Proceedings, Part III. pp. 607–616. Springer-Verlag, LNCS 4556 (2007).
14. Savidis, A., Stamou, A., Stephanidis, C.: An Accessible Multimodal Pong Game Space. Universal Access in Ambient Intelligence Environments. 405–418 (2007).
15. Gutschmidt, R., Schiewe, M., Zinke, F., Jürgensen, H.: Haptic Emulation of Games : Haptic Sudoku for the Blind. PETRA '10 Proceedings of the 3rd International Conference on PErvasive Technologies Related to Assistive Environments. p. Article 2. ACM, Samos, Greece (2010).
16. Westin, T.: Game accessibility case study: Terraformers – a real-time 3D graphic game. 5th Intl Conf. Disability, Virtual Reality & Assoc. Tech., Oxford, UK. , Oxford, UK (2004).
17. Atkinson, M.T., Gucukoglu, S., Machin, C.H.C., Lawrence, A.E.: Making the mainstream accessible: redefining the game. Sandbox Symposium 2006, ACM SIGGRAPH Symposium on Videogames. pp. 21–28. , Boston, Massachusetts (2006).

18. Allman, T., Dhillon, R.K., Landau, M.A.., Kurniawan, S.H.: Rock Vibe: Rock Band® computer games for people with no or limited vision. Proceedings of the 11th international ACM SIGACCESS conference on Computers and accessibility. pp. 51–58. ACM (2009).
19. Yuan, B., Folmer, E.: Blind hero: enabling guitar hero for the visually impaired. Proceedings of the 10th international ACM SIGACCESS conference on Computers and accessibility. pp. 169–176. ACM (2008).
20. Savidis C. Stephanidis, A.: Unified User Interface Design: Designing Universally Accessible Interactions. International Journal of Interacting with Computers. 16, 243–270 (2004).
21. MediaLT: Guidelines for developing accessible games, http://gameaccess.medialt.no/guide.php, (2006).
22. Game Accessibility Guidelines: A straightforward reference for inclusive game design, http://www.gameaccessibilityguidelines.com/, (2012).
23. W3C: Authoring Tool Accessibility Guidelines, 2.0, http://www.w3.org/TR/ATAG20/, (2012).
24. Grammenos, D., Savidis, A., Stephanidis, C.: Designing universally accessible games. ACM Computers in Entertainment. 7, Article 8 (2009).
25. Grammenos, D., Savidis, A., Georgalis, Y., Stephanidis, C.: Access Invaders: Developing a Universally Accessible Action Game. In: Miesenberger, K., Klaus, J., Zagler, W.L., and Karshmer, A.I. (eds.) Computers Helping People with Special Needs: 10th International Conference, ICCHP 2006, Linz, Austria, July 11-13. pp. 388–395. Springer-Verlag, LNCS 4061 (2006).
26. Archambault, D., Olivier, D.: How to Make Games for Visually Impaired Children. Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology (ACE'05). pp. 450–453. ACM (2005).
27. Roden, T., Parberry, I.: Designing a narrative-based audio only 3D game engine. Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology - ACE '05. pp. 274–277. ACM Press, New York, New York, USA (2005).
28. Friberg, J., Gärdenfors, D.: Audio Games: New perspectives on game audio. Proceedings of the 2004 ACM SIGCHI International Conference on Advances in computer entertainment technology (ACE'04). pp. 148–154. ACM, Singapore (2004).
29. Somethin'Else: Papa Sangre, http://www.papasangre.com/, (2013).
30. Sánchez, J., Espinoza, M.: Audio haptic videogaming for navigation skills in learners who are blind. The proceedings of the 13th international SIGACCESS conference on accessibility (ASSETS). 227–228 (2011).
31. Sánchez, J.: Development of Navigation Skills Through Audio Haptic Videogaming in Learners Who are Blind. Procedia Computer Science. 14, 102–110 (2012).
32. Miller, D., Parecki, A., Douglas, S.A.: Finger dance: a sound game for blind people. Proceedings of the 9th international ACM SIGACCESS conference on Computers and accessibility (ASSETS'07). pp. 253–254. ACM (2007).
33. De Pascale, M., Mulatto, S., Prattichizzo, D.: Bringing Haptics to Second Life for Visually Impaired People. Haptics: Perception, Devices and Scenarios. LNCS 5024, 896–905 (2008).
34. Sjöström, C., Rassmus-Gröhn, K.: The sense of touch provides new computer interaction techniques for disabled people. Technology and Disability. 10, 46–52 (1999).
35. Kim, J., Ricaurte, J.: TapBeats: accessible and mobile casual gaming. 13th international ACM SIGACCESS conference on Computers and accessibility (ASSETS 2011). pp. 285–286. ACM (2011).
36. Morelli, T., Foley, J., Columna, L., Lieberman, L., Folmer, E.: VI-Tennis : a Vibrotactile / Audio Exergame for Players who are Visually Impaired Categories and Subject Descriptors. Proceedings of the Fifth International Conference on the Foundations of Digital Games (FDG'10). pp. 147–154. ACM (2010).
37. Brewster, S.A.: Using nonspeech sounds to provide navigation cues. ACM Transactions on Computer-Human Interaction. 5, 224–259 (1998).

38. Sánchez, J., Sáenz, M., Ripoll, M.: Usability of a Multimodal Videogame to Improve Navigation Skills for Blind Children. Proceedings of the 11th international ACM SIGACCESS conference on Computers and accessibility (ASSETS'09). pp. 35–42 (2009).
39. Trewin, S., Hanson, V.L., Laff, M.R., Cavender, A.: PowerUp: an accessible virtual world. Proceedings of the 10th international ACM SIGACCESS conference on Computers and accessibility - Assets '08. pp. 177–184. ACM, New York, NY, USA (2008).
40. Lécuyer, A., Lotte, F., Reilly, R.B., Leeb, R., Hirose, M., Slater, M.: Brain-Computer Interfaces, Virtual Reality, and Videogames. Computer. 41, 66–72 (2008).
41. Huo, X., Ghovanloo, M.: Evaluation of a wireless wearable tongue–computer interface by individuals with high-level spinal cord injuries. Journal of Neural Engineering. 7, 26008 (2010).
42. Argue, R., Boardman, M., Doyle, J., Hickey, G.: Building a Low-Cost Device to Track Eye Movement, http://web.cs.dal.ca/~boardman/eye.pdf, (2004).
43. Sporka, A.J., Kurniawan, S.H., Mahmud, M., Slavík, P.: Non-speech Input and Speech Recognition for Real-time Control of Computer Games. 8th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS 2006). pp. 213–220. ACM Press, Portland, Oregon, USA (2006).
44. Norte, S., Lobo, F.G.: Sudoku Access : A Sudoku Game for People with Motor Disabilities. 10th international ACM SIGACCESS conference on Computers and accessibility (ASSETS 2010)2. pp. 161–167. ACM, Halifax, Nova Scotia, Canada (2010).
45. Heron, M.: Inaccessible through oversight : the need for inclusive game design. The Computer Games Journal. 1, 29–38 (2012).
46. Archambault, D., Gaudy, T., Miesenberger, K., Natkin, S., Ossmann, R.: Towards Generalised Accessibility of Computer Games. In: Pan, Z., Zhang, X., Rhalibi, A. El, Woo, W., and Li, Y. (eds.) Technologies for E-Learning and Digital Entertainment, Third International Conference, Edutainment 2008, Nanjing, China, June 25-27. pp. 518–527. Springer Heidelberg, LNCS 5093 (2008).
47. DeafGamers.com: Half-Life 2, game review, http://www.deafgamers.com/04_05reviews/half-life2_pc.htm, (2005).
48. GarageGames: Closed Captioning, http://www.garagegames.com/community/resources/view/13437, (2007).
49. Brashear, H., Henderson, V., Park, K., Hamilton, H., Lee, S.: American Sign Language Recognition in Game Development for Deaf Children. 8th international ACM SIGACCESS conference on Computers and accessibility (ASSETS 2006). pp. 79–86 (2006).
50. Adamo-villani, N., Wright, K.: SMILE : an immersive learning game for deaf and hearing children. ACM SIGGRAPH. p. 17 (2007).
51. Lanyi, C.S., Brown, D.J.: Design of Serious Games for Students with Intellectual Disability. In: Joshi, A. and Dearden, A. (eds.) IHCI'10 Proceedings of the 2010 international conference on Interaction Design & International Development. pp. 44–54. British Computer Society Swinton, UK (2010).
52. Gaggioli, A., Gorini, A., Riva, G.: Prospects for the Use of Multiplayer Online Games in Psychological Rehabilitation. Virtual Rehabilitation, 2007. pp. 131–137 (2007).
53. Hobbs, D., Henschke, M., Wilkinson, B., Reynolds, K.: Game on! Accessible gaming for children with disabilities. National Conference of the Australian Rehabilitation & Assistive Technology Association (ARATA). , Sydney, Australia (2012).
54. Lotan, M., Yalon-Chamovitz, S., Weiss, P.L.T.: Improving physical fitness of individuals with intellectual and developmental disability through a Virtual Reality Intervention Program. Research in developmental disabilities. 30, 229–39 (2009).
55. Kueider, A.M., Parisi, J.M., Gross, A.L., Rebok, G.W.: Computerized cognitive training with older adults: a systematic review. PloS one. 7, e40588 (2012).
56. Ohring, P.: Web-based multi-player games to encourage flexibility and social interaction in high-functioning children with autism spectrum disorder. Proceedings of the 7th international

conference on Interaction design and children. pp. 171–172. ACM, New York, NY, USA (2008).
57. Coles, C.D., Strickland, D.C., Padgett, L., Bellmoff, L.: Games that “work”: using computer games to teach alcohol-affected children about fire and street safety. Research in developmental disabilities. 28, 518–30 (2007).
58. Torrente, J., Del Blanco, Á., Marchiori, E.J., Moreno-Ger, P., Fernández-Manjón, B.: <e-Adventure>: Introducing Educational Games in the Learning Process. IEEE Education Engineering (EDUCON) 2010 Conference. pp. 1121–1126. IEEE, Madrid, Spain (2010).
59. Moreno-Ger, P., Burgos, D., Sierra, J.L., Fernández-Manjón, B.: Educational Game Design for Online Education. Computers in Human Behavior. 24, 2530–2540 (2008).
60. Dickey, M.D.: Game Design Narrative for Learning: Appropriating Adventure Game Design Narrative Devices and Techniques for the Design of Interactive Learning Environments. Educational Technology Research and Development. 54, 245–263 (2006).
61. Amory, A.: Building an Educational Adventure Game: Theory, Design and Lessons. Journal of Interactive Learning Research. 12, 249–263 (2001).
62. Garris, R., Ahlers, R., Driskell, J.E.: Games, Motivation and Learning: A Research and Practice Model. Simulation & Gaming. 33, 441–467 (2002).
63. Torrente, J., Vallejo-Pinto, J.Á., Moreno-Ger, P., Fernández-Manjón, B.: Introducing Accessibility Features in an Educational Game Authoring Tool: The Experience. Advanced Learning Technologies ICALT 2011 11th IEEE International Conference on. pp. 341–343. Ieee (2011).
64. Torrente, J., Del Blanco, Á., Moreno-Ger, P., Fernández-Manjón, B.: Designing Serious Games for Adult Students with Cognitive Disabilities. In: Huang, T., Zeng, Z., Li, C., and Leung, C. (eds.) Neural Information Processing, Lecture Notes in Computer Science Volume 7666. pp. 603–610. Springer Berlin Heidelberg (2012).

Mr. Javier Torrente, MSc, got his degree in Computer Science from Complutense University of Madrid in 2008, and his Master Degree in 2009. Since 2008 he works as a contract researcher for the University Complutense of Madrid, in the group of educational technologies and e-learning e-UCM. His research mainly focuses in the field of Game-Based Learning in general and the eAdventure project in particular. He's coauthor of more than 40 academic papers published in international conferences and journals of the field. He has also participated in numerous R&D projects at national, European and international level, like the ProActive LLP project, funded by the European Commission (www.proactive-project.eu).

Mr. Ángel del Blanco, MSc, finished his Master Degree in Computer Science at the UCM in 2009, and currently he is working as a full-time researcher in the e-UCM research group as well as being a PhD student. His research focuses on the technical integration of highly interactive contents into e-learning environments, with special emphasis in the current e-learning standards and its limitations. He has published 24 research papers in academic journals and conferences in the field. He is part of the e-learning CTN71/SC36 technical committee under the Spanish Standard Organization AENOR.

Mr. Ángel Serrano-Laguna, MSc, works for the Complutense University of Madrid as a researcher in the e-UCM e-learning group as well as being a PhD student. His current research interests are educational video games, learning analytics and the eAdventure project. He has published 8 academic papers related to these topics.

Dr. José Ángel Vallejo-Pinto, PhD, got a PhD in Telecommunications Engineering from the Universidad Politécnica de Madrid (UPM) in 1998, working as a member of the Speech Technology Group, and participating in several R&D projects and papers related to speech processing. He works as associated professor at the Department of Computer Science of the Universidad de Oviedo since 2002. He has cooperated with the e-UCM e-learning group in several papers related to e-Learning and with members of the Department of Applied Economics of the Universidad de Oviedo in the field of inter-port competition.

Dr. Pablo Moreno-Ger, PhD, finished his doctorate in informatics engineering from Universidad Complutense de Madrid (UCM) in 2007. He is current an Associate Professor in the Department of Software Engineering and Artificial Intelligence, UCM, where he teaches and carries out his research work. He specializes in technology-assisted teaching and his current research interests are centered on the use of video games and simulations with educational aims, as well as the integration of these interactive technologies in e-learning environments. He has published over 70 academic papers in the field.

Dr. Baltasar Fernández-Manjón, PhD, got his PhD in Physics from the Universidad Complutense de Madrid (UCM). He is currently Full Professor at the School of Computer Science at the UCM. He is director of the e-UCM research group and his main research interests include e-learning technologies, application of educational standards and serious games on which he has published more than 120 research papers. Dr. Fernández Manjón is also member of the Working Group 3.3 “Research on the Educational uses of Communication and Information Technologies” of the International Federation for Information Processing (IFIP) and a member of the Spanish Technical Committee for E-learning Standardization (AENOR CTN71/SC36).