From Screens to Devices and Tangible Objects: A Framework Applied to Serious Games Characterization

Julian Alvarez[1,2], Sylvain Haudegond[1], Clémentine Havrez[1,3], Christophe Kolski[3], Yoann Lebrun[1,3], Sophie Lepreux[3], and Aurélien Libessart[2]

[1] Play Research Lab., CCI Grand Hainaut
{j.alvarez,s.haudegond,y.lebrun}@grandhainaut.cci.fr
[2] Trigone Cirel, Lille1 University
{julian.alvarez,aurelien.libessart}@univ-lille1.fr
[3] LAMIH -UMR CNRS 8201, University of Valenciennes, France
{clementine.havrez,christophe.kolski,yoann.lebrun,
sophie.lepreux}@univ-valenciennes.fr

Abstract. The accelerated progress being made with interactive devices (such as screens, cameras, joysticks and tangible objects) has triggered the development of new interaction methods for applications (e.g., body language, haptic feedback, etc.). Video games and Serious Games are being played on increasingly innovative peripherals (e.g., Kinect, Wii Balance Board). These devices have generated new, intuitive forms of Human-Computer Interaction that are completely changing our usages. The purpose of this paper is to provide an overview of gaming technologies and suggest a framework for characterizing the role that screens play in these devices. This framework differentiates between the various gaming elements (the gamers, the interactive devices and the entertaining and gamified applications). This framework is a tool to analyze the effects of device choice and configuration. This paper presents an evaluation of the characterization of 15 serious games. This evaluation will provide a glimpse of the potentialities of the framework with respect to suggested criteria as well as of the trends and potential developments in interactive media.

Keywords: Tangible objects, screens, devices, video game, serious game, characterization.

1 Introduction

We are increasingly surrounded by screens, and more generally speaking, by devices that provide various ways to interact with different types of applications (see Fig. 1). Video games, and conceivably serious video games (Serious Games [0]), regularly offer innovative technologies and usages [2, 3]. The increasing intuitiveness of Human-Computer Interaction (HCI) enables interactive devices to be more and more rapidly appropriated by users [4]. For example, households are acquiring peripherals like Kinect or the Wii Balance Board with increasing frequency [5]. We believe that the challenges to be faced in the next few years will be tangibility, and even more so,

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the combination of the tangible with the virtual. The commercial success of the *Skylanders* (from Activision in 2011) and *Disney Infinity* (from Disney in 2013) tangible objects that rely on NFC technology to manage video game avatars, or games like *AppMates* (from Disney Pixar in 2012) *Apptivity toys* (from Mattel in 2013) and *Cupets* (from Giochi Preziosi in 2013), which can directly communicate with tablets, supports our hypothesis.

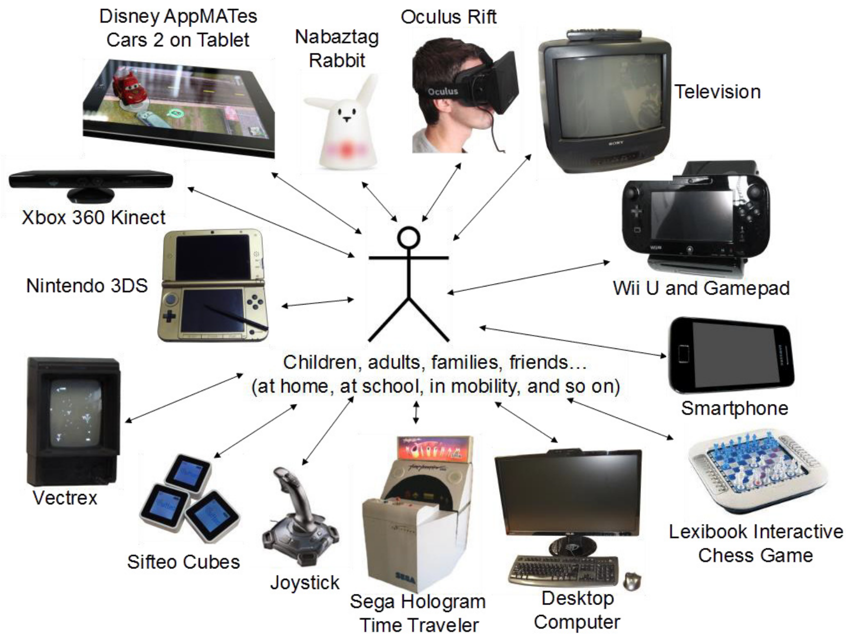

Fig. 1. What was the screen invasion has become the interactive media invasion

This is why we wanted to focus on the state of the art in video gaming (Serious or otherwise) in this paper to suggest a framework for characterizing the role of screens in such applications. This characterization focuses mainly on gaming peripherals and devices proposed by Saunders and Novak [6]. The research presented in this paper is comprised of a preliminary study whose objective was to examine the contribution made by video gaming and Serious Games in acquiring knowledge and skills, particularly in the areas of health, education and communication. We specifically refer to the potential facilitation of the skills transfer from the virtual environment to the real world that goes along with associating screens with tangible objects in a gaming context [7]. However, to conduct such research, it was appropriate first to prepare experiments to confirm or refute the hypotheses. To do this, it seemed to us that identifying the different variables that could be assembled within gaming devices through characterization represented a necessary, pragmatic approach.

The second section of this article provides an overview of current gaming technologies. This overview is not intended to be exhaustive, but rather representative of the various gaming configurations corresponding to technological breakthroughs over the years. In the third section, we suggest a framework for categorizing the games. This framework is applied in section four on 15 different Serious Games. The article finishes with a conclusion and suggestions for future research.

2 Study of Technological Developments and Breakthroughs Related to the Use of Screens and Objects in Interactive Entertainment Applications

In this state of the art section, different technological developments and breakthroughs will be reviewed and then summarized.

2.1 The Beginning: The First Display not Incorporated into a Calculator (OXO, 1952)

From the very beginning, video games have used a screen and an input interface, as illustrated in the OXO case. Created by English IT specialist Alexander S. Douglas, this tic-tac-toe game [8] was programmed into the EDSAC (Electronic Delay Storage Automatic Calculator) computer at the University of Cambridge. The EDSAC computer was able to store programs in its memory (similar to the RAM of today's computers). This device had three CRT screens displaying the current state of the memory in graphical form. Douglas's idea was to take this memory monitoring functionality and use it as a graphical display tool. As an IT student, Douglas conducted research on Human-Computer Interaction. In his academic thesis, he came up with the idea of programming a game, which illustrated the result of his work. The CRT control screen, which had a resolution of 35 x 16, was programmed to display a tic-tac-toe board as well as the signs placed by the players. The computer control panel had a rotary telephone dial. The researcher used it as a "joystick". To play, users simply needed to dial a number to indicate the box chosen for their sign.

2.2 Then Came the Joysticks... Tennis for Two (1958)

Tennis for Two, a *Pong* predecessor, was undoubtedly the first video game in history to associate potentiometers with computers to serve as joysticks. This game was designed by William A. Higinbotham. He dissected a Donner analog computer in search of ideas, and the "bouncing ball" program presented in the machine's instruction manual made him think of a tennis match. Thus, *Tennis For Two* was born. The game was improved in 1959. This new version enabled users to play with gravity settings, such as "on the Moon" or "on Jupiter", and had a larger display (increasing in size from 12 cm in the first version to 30 cm in the new version). After two years of loyal service, the game was dismantled and the famous joysticks were discarded.

2.3 Multimodal Interaction: From JoyBoard to Dataglove

It was not long after the emergence of video games that their designers began to explore different gaming modalities. The Magnavox Odyssey, which in 1972 became the first video game launched on the consumer market, offered the Light Gun peripheral (from Magnavox in 1972). This option used a rifle attached to the console. The rifle had an optics system to simulate on-screen shooting. This steering wheel enabled gamers to enjoy a heightened sensation of driving on a road at night [9]. The Atari VCS 2600 video game, which was launched in 1977, offered a wide range of peripherals throughout its life cycle, such as the Joyboard (from Amiga in 1982). It looked like a black bathroom scale and enabled gamers to guide a virtual skier using their feet. The JoyBoard may be considered the ancestor of the Nintendo Wii Balance Board, which was launched in 2007. Nintendo has also provided various video game playing methods throughout its history. FAMICOM offered a microphone on its joysticks when the console was first launched in 1983. This functionality enabled gamers to play while incorporating speech, singing or whistling. In 1989, Mattel explored motion detection with the Power Glove (from Mattel in 1989) peripheral for the NES console. In 1995, Nintendo began exploring Virtual Reality with the Virtual Boy console. This console resembled a set of binoculars placed on a tripod. The binoculars offered a red monochromatic display, endowing gamers with stereoscopic vision. Since it was suspected of causing migraines, the console did not enjoy the commercial success it was intended to have. The aforementioned examples are not an exhaustive list, but rather a representative sample of the diversity of modalities explored and developed by the video gaming industry over time. Today, this dynamic environment continues to develop with an increasing number of control methods and tangible objects (such as Kinect, Oculus Rift and the Skylanders figurines), which complete the video gaming picture.

2.4 Integrated Display Objects: Portable Electronic Games

In 1976, the American Mattel Electronics company launched what was probably one of the first mass market portable electronic games: *Auto Race*. In concrete terms, the video game device was a handheld white box. The race cars were represented by vertical red dashes that moved from the top to the bottom of the screen. In 1979, Milton Bradley launched Microvision. This was a device with interchangeable game cartridges and a 16 x 16 pixel black and white liquid crystal display. Devices were becoming more sophisticated. However, it was really the 1980 arrival of *Game&Watch*, launched by Gunpei Yokoi (from Nintendo in 1980) with a dedicated image for each object, that advances were truly made. Even though each Game&Watch only had one game, the device was a success. Nintendo revamped the Microvision concept with the 1989 launch of the Game Boy. This device had interchangeable game cartridges to be used with a single screen and command panel, in contrast to its predecessor, for which the interchangeable element was an entire block containing the command panel, the printed circuit board and the game display. The Game Boy offered a 160 x 144 pixel display with four different shades of gray. With such high resolution, the representations became more sophisticated for the players of that time: 118 million Game Boys ended up being sold across the globe.

2.5 Relationship between Input and Output Modalities: From Light Pen to Interactive Table

Two different approaches represent attempts to relate input and output modalities. Based on the first approach, Moonlander, designed by Jack Burness en 1973, invited gamers to land a space module on a lunar platform using gravity and fuel reserves.

This game was financed by the North American Digital Equipment Corporation (DEC) to promote the technical characteristics of the DEC GT40: vector graphics and a light pen. This meant that Moonlander users could guide the space module by adjusting the throttle value and the angle of the lunar lander with the light pen. Moonlander was part of a marketing campaign to demonstrate the technical qualities of a machine at commercial exhibitions.

Interactive tables represent a second approach to these new, supposedly interactive applications. Interactive tables have a surface that acts both as a screen and a detection device (with integrated or external detection mechanisms). The technical input tools for these devices can be tactile (e.g., DiamondTouch by P. Dietz and D. Leigh [10]) or tangible through the manipulation of objects on the table surface. For example, the TangiSense [11] interactive table detects objects equipped with RFID technology; the Serious Game described in [12], which is used to help teach colors and color recognition to children aged 3 to 6 years, provides learners and teachers with specific tangible objects; this Serious Game represents new tangible object applications for educational contexts.

2.6 Multiscreen Applications for Single and Multiple Gamers

There are different ways to integrate multiple screens into video games. The use of several screens can expand the standard gamer view, like in the *TX-1* racing game (from Tatsumi Electronics Company in 1983). This arcade video game has three screens to enable gamers to better immerse themselves in the gaming experience. Multiscreen gameplay can also be seen on portable devices, such as with *Donkey Kong* on the "Game & Watch Multi Screen" (both from Nintendo in 1982). A multiscreen device can also provide additional, independent visual information, like the Nintendo DS and the *Super Mario 64 DS* game (both from Nintendo in 2005). In this example, there is a 2D view on an upper screen and a third-person 3D view on the other screen. Furthermore, this console enables users to use touch control on one of the two screens.

In the preceding examples, gamers have access to several screens on a single device. However, a single player may also use several devices to play a single game. The *Tom Clancy's Splinter Cell* game (from Ubisoft in 2003), which can be used both on GameCube (from Nintendo in 2001) and Game Boy Advance (from Nintendo in 2001), is an example.

There are also multiplayer possibilities. Gamers can each have their own gaming device and screen while interacting with each other. For example, using *Cable Link* (Nintendo) two people could play the *Tetris* version released on the Game Boy (from Nintendo in 1989). Players can also interact on the same game using different devices. *Pac-Man World 2* (from Namco in 2003) offers *Pac-Man Vs.* as a bonus. *Pac-Man Vs.* enables one player to control *Pac-Man* using the GameCube and other players to control the ghosts with Game Boy Advance. Each gamer has their own view, and therefore engages in asymmetric gameplay.

2.7 The First Networked Games: Spacewar PLATO, Maze War and MUD

One of the first networked video game applications dates back as early as 1969, with a two player version on the MIT PLATO system's *Spacewar* game. The game's designer was Rick Blomme. The PLATO system gave rise to Multi-User Dungeon

(MUD) in 1978. These were textual, multiplayer networked games inspired by the traditional *Dungeons & Dragons*. However, it was in 1973 that what was undoubtedly the first client-server networked game, *Maze War*, was released. Designed by Greg Thompson, this game enabled up to eight IMLAC systems to network through a DEC-20 mainframe to play against each other. Then, through the DEC-20 mainframe's connection on the ARPANET network, access to the *Maze War* game was open to anyone with an IMLAC system using TIP and NCP protocols.

2.8 Motion and Interaction: From Mandala VR to Kinect

In 1997, the Canadian Vivid group company launched Mandala VR system that uses visual user recognition to incorporate users into audiovisual environments and enable interaction through motion sensors. Mandala VR was incorporated into games, such as *Airborne Rangers*, *City Gx*, *Meteor Storm* and *Formula Gx*. This concept mainly targeted televised games. In 1998, Nintendo launched *Game Boy Camera*, also known as *Pocket Camera*. With 256 x 226 pixel definition and four shades of gray, this device was inserted into the Game Boy cartridge slot and enabled users to take photographs that could then be incorporated into a game, if desired. This is the case, for example, with *Space Fever II*, in which the end-of-level-enemy was represented by the gamer's face. Motion detection was also used in the *Ball* game, in which users were invited to employ their hands to catch and throw balls.

EyeToy from Sony was launched in 2003, and in 2007, the "Playstation Eye" was incorporated into the Playstation 3 console, which was further improved in 2010 with the *Playstation Move* system. This system was intended to compete with the Wii motion detection system, released in 2006, and the binocular *Kinect* camera, launched in 2010 by Microsoft for exclusive use with its Xbox 360 console.

2.9 Summary

Historically examining video game state of the art from OXO in the early 50s to the present reveals various significant technological trends and breakthroughs in terms of input and output devices made available to gamers. Figure 1 provides an overview of the diversity of these devices.

This overview illustrates various concepts related to the configuration of these devices, although this list was not exhaustive. Subsequently, both single screen and multi-screen configurations have existed. Single and multiple player consoles have also existed. Today, various single and multi-user configurations are available. A single screen can be used by one gamer or be shared by several gamers. A single application can be centralized on a network for use by multiple gamers. A single gamer can stay in one place (i.e., be static) or be mobile. Gameplay can be symmetric or asymmetric. Such concepts will be used in the framework suggested in the following section.

3 Proposal for a Framework for Characterizing Entertainment and Gamified Devices

Thanks to the state of the art, we have seen different concepts for characterizing video game consoles that have evolved over time with advances in technology. The study does not aim to analyze the adaptation of devices to user needs and characteristics. Rather, it endeavors to focus on the properties of the media. These concepts are not complete, but initially, they will enable us to define the applications targeted by our study so that in future research efforts, we can draw conclusions on the impact that choice of medium and medium configuration has on learning. We chose the entity-relationship model defined by Chen [13] to represent the framework (see Fig. 2) proposed in this paper.

Entertaining and gamified applications refers to the application (software) being studied. After establishing the state of the art, we noticed that the number of players for which an application was designed, as well as the symmetry of gameplay, could influence the structure (unless the game was created for a particular structure that already defined the maximum possible number of players - it all depends on the design process [14, 15]). By symmetry, we mean the way in which gamers interact with the game, and the objectives to achieve can differ with the roles, if any, offered to gamers. In section 2.6, and especially the GameCube - Game Boy Advance interconnectivity example, we saw that symmetry can affect user experience, and we wonder about the impact that this could have on learning. Being able to play a game on a network, one of the developments discussed in our state of the art section, was added as configuration-defining element.

The interactive application is offered on at least one type of media, i.e., the Interactive device. In our model, cardinality (1, n) refers to the fact that several devices can be used for a given gaming experience, like in the aforementioned *Pac-Man Vs* example. We are not referring to the application portability concept. For each device, we specify its mobility (portable, like the Nintendo DS, or static, like the Microsoft Xbox 360 home console), the positioning of its screen(s) (whether the screen is integrated into the device or external to the device, like a television). Since some devices enable gamers to change their configuration in space, like Sifteo Cubes (from Sifteo Inc. in 2011), which can be moved relative to each other, turned and shaken, the User-adjustable parameter was added. Regarding the link between an application and its medium or media, we specify the number of screens that can or must be used by the gaming device. The *Tom Clancy's Splinter Cell* game requires gamers to use the GameCube, but can use the Game Boy Advance screen as well. This is therefore a multi-screen case.

Since games only function and make sense when they are played [16], the Gamer element is obviously crucial to our model. This is not only because gamers are the direct target of applications, but also because it is the gamers who use the device(s) to interact with a game. Gamers and devices can communicate with each other in many ways, whether through a joystick and a screen or through tangible objects, movements and sounds. This element is defined in our model as the Type of interaction. We selected gamer cardinality (0, n) since certain games, like *Tank Attack* (from CDS in 1989) do not require gamers to interact with the medium. This type of war game uses a traditional gaming platform representing a geological survey map on which gamers can move their armored military units. The computer arbitrates the game and manages the different game events, such as dice rolling and combat outcomes.

Finally, gamers are not required to play alone. They can play with other gamers in the same place (i.e., be colocated) or in different locations (networked games).

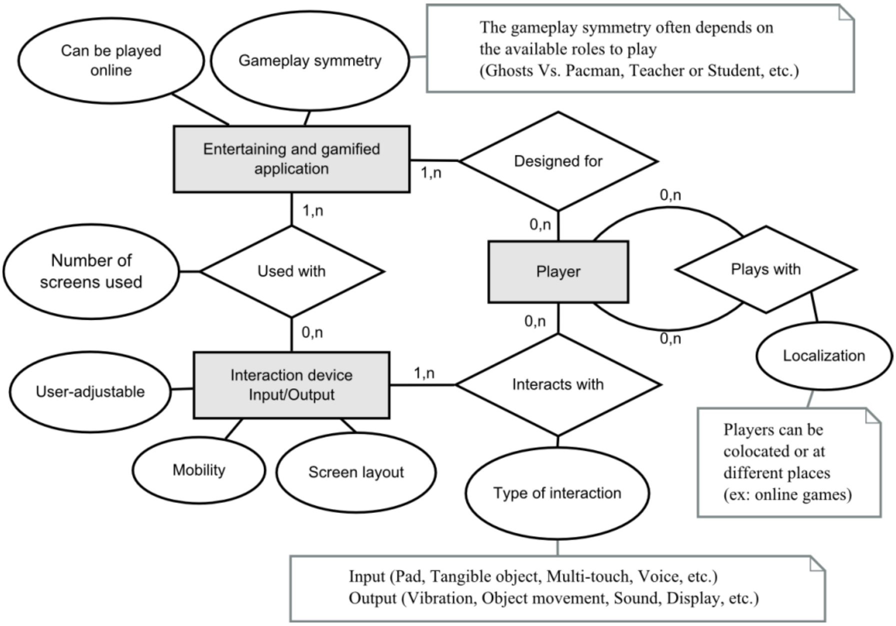

Fig. 2. Presentation of the framework in EA model

This framework enables us to characterize Entertainment and gamified devices to study the effects of their configuration on learning. In the following section, we suggest using the components of this framework to analyze the characteristics of 15 Serious Games.

4 Validation of Serious Games through Characterization

In this section, we suggest validating the framework presented in the previous section (Section 3) by characterizing 15 Serious Games. This involves identifying major trends and using the obtained results to identify possibilities for novel forms of interaction.

The table (Table 1) presents 15 Serious Games characterized according to a set of criteria. These criteria were selected using the suggested framework for defining the following aspects:

- Multi-display: indicates the presence of one or more displays in the Serious Game to provide users with different visual feedback perspectives.
- Multi-user: enables several users to interact simultaneously. The interaction can be colocated (i.e., the users are next to each other in the same room) or remote (i.e., the users are in different, distant locations).
- Display/control panel interaction: possible interactions take place in one of three different ways. Intangible mode characterizes interactions that do not provide haptic feedback to the gamer (such as through movement-related or vocal interactions). Tangible mode indicates what can be felt by touch. Immersive tangible

mode further integrates the ability to superimpose a virtual environment on the perception we have of reality (the augmented reality concept).

- Multi-device: indicates that the Serious Game can be used locally on several devices.
- Layout: refers to the layout of the display. In this context, the display can be separated from/integrated into the medium/control panel.
- Mobility: indicates whether or not the device can be easily transported.
- Gameplay: distinguishes the various roles associated with users while the game is being played.
- Networked game: refers to Serious Games that do not require any installation or that are played using an Internet connection.
- Adjustable: The device can be reconfigured in space by the user.

The Serious Games identified and numbered in the table are as follows:

(1) *Hunet Island* (form Orange in 2009) an interactive table game whose purpose is to raise client awareness of electronic invoicing.

(2) *Flee the Skip* (from Orange in 2010) is played by four people. Its purpose is to encourage solidarity among gamers confronted with a given challenge, and to do so within 20 minutes.

(3) *Thélème* (from Almédia in 2009) is a French language learning game in the form of a massive, multi-participant online adventure game.

(4) *Motion Math* (from Motion Math in 2010) is a series of several entertaining iPhone / iPad applications that teach basic math concepts.

Table 1. Characterization of the 15 Serious Games

SG / **Criteria**											0	1	2	3	4	5
Multi-display																
Multi-user	**Colocalised**															
	Remote															
Display/ Control Panel Interaction	**Intangible**															
	Immersive Tangible															
	Tangible															
Multi-device																
Layout	**Independent**															
	Integrated															
Mobility																
Game-play	**Symmetric**															
	Asymmetric															
Networked games																
User adjustable																

(5) *Trions et rangeons tout* (from Donuts in 2009) is a waste sorting game that uses tangible objects (waste bins and waste items) to encourage proper waste sorting behaviors.

(6) *America's Army (*from US Army in *2003)* is a multi-player tactical first person shooter game used by the US Army to improve its image and encourage people to enlist. It is available on Windows, PlayStation 2, Xbox and as an arcade video game.

(7) *Mission BRAQUO* (from Canal+ in 2011) is an interactive ARG available on several types of media (such as the Internet and mobile phones). Players must extricate themselves from difficult situations. To do so, they receive e-mails, text messages and multimedia messages at all hours of the day and night.

(8) *Dr. Kawashima's Brain Training: How old is your brain?* (from Nintendo in 2005) is a group of mini brain training games (e.g., mental arithmetic, logic and reading).

(9) *Flower Breath* (from V. Chritin, E. Van Lancker, X. Falourd and B. Bouzin in 2007) uses Positive Expiratory Pressure (PEP) devices to help pediatric Cystic Fibrosis patients have fun while performing their daily breathing exercises.

(10) *Mind Force Defense* (from Macrotellec in 2012) uses brain sensors to help children learn how to focus.

(11) *I-CARE* (from Eurocopter/University of Toulon in 2011) teaches how to manage information overflow during a flying mission. The situations are based on real cases, but the cases are staged in an entertaining way.

(12) *StoryBOX* (from Waag Society in 2011) uses technologically enhanced tangible objects to help with language learning. The players learn to express themselves by physically relying on words and concepts in their daily life.

(13) *Voracy Fish* (from Genious in 2012) is a multiplayer game that uses various peripherals for the functional rehabilitation of the upper limbs (e.g., Kinect, LEAP Motion).

(14) *Hammer and Planks* (from NaturalPad in 2013) enables hemiplegic patients regain their balance. It is a multiplayer game that can be used with the Nintendo Wii Board, Kinect, Xbox joysticks on PCs, touchscreens, tablets and smartphones.

(15) *You are blind (*http://youareblind.com/) helps educate seeing people about blind children. It uses a webcam to detect the gamer's movement's and transmit them to the game.

All the criteria in the table are associated with at least one Serious Game. Certain criteria (such as Symmetric gameplay and Independent multi-device) are used more often than others, which helps predict significant future Serious Gaming trends. It is possible to more closely examine these criteria to make them more intuitive for users and to integrate them into devices.

Moreover, Gameplay is generally characterized as symmetric, which leaves the asymmetric concept unexplored. Yet, this type of game design can help distinguish various forms of gameplay in a single Serious Game. This involves adjusting games to gamers' habits as well as adapting games to disabled gamers (in terms of mobility and concentration, for example).

Finally, we can mention the idea that the video gaming industry influences Serious Games. For example, the Kinect and Wii Balance Board have become somewhat standard in Serious Games (see SG 13 and 14 in Table 1). Conversely, Serious Games can also affect the video gaming industry by introducing modalities, like *Flutter* (the breathing device for lung vibration therapy, SG 9) and adjustable systems (see SG 12). These ideas need to be reinforced by characterizing significant and representative data.

5 Conclusion

The word is rapidly changing with the increasingly extensive introduction of all different types of screens as well as with the generalization of interactive media to the home, public spaces, the workplace, schools, universities and other learning environments. This generalization is true regardless of whether media are static or mobile, collective or individual.

Given these observations and the possibility of studying media intended mainly for skills transfer, we initially examined the technological developments and breakthroughs related to using displays and objects in interactive entertainment applications. We revealed key concepts in our summary of this study. This made it possible for us suggest an initial framework for characterizing Entertainment and gamified devices. To validate this framework, we used it to characterize a sample of 15 Serious Games using various types of devices to represent different trends. The initial results are promising, and provide us with various possibilities for future research and improvement.

It would be possible to expand this framework in future research by explicitly integrating other concepts, this time related to the type of application, and more specifically Serious Games. We could also expand the framework to incorporate gamer motivations, both in terms of learning and more generally in terms of user experience. This characterization framework should make it possible to improve Serious Games referenced in the database available at http://serious.gameclassification.com [17].

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