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Review Article

An Overview of Serious Games

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Serious games are growing rapidly as a gaming industry as well as a field of academic research. There are many surveys in the field of digital serious games; however, most surveys are specific to a particular area such as education or health. So far, there has been little work done to survey digital serious games in general, which is the main goal of this paper. Hence, we discuss relevant work on serious games in different application areas including education, well-being, advertisement, cultural heritage, interpersonal communication, and health care. We also propose a taxonomy for digital serious games, and we suggest a classification of reviewed serious games applications from the literature against the defined taxonomy. Finally, the paper provides guidelines, drawn from the literature, for the design and development of successful serious games, as well as discussing research perspectives in this domain.

1. Introduction

The idea of playing a game dates to the ancient past and is considered an integral part of all societies. For instance, Dice appears to be among the earliest games used by humans, the oldest known example is a 3000 year old game set in south Iran [1]. Some of these games already served a "serious" purpose; for example, Mancala (a game designed around 1400 BC) was used as an accounting tool for trading animals and food [2]. However, most games were based on the concept that the game contains and reveals knowledge that is otherwise hidden from the player.

In recent history, several landmarks have marked the development of serious games as summarized in Table 1 and described in this section and can probably be considered milestones in the history of serious games. The concept of serious games was first coined by Abt [3] and described as follows: "We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement." He used innovative gaming approaches to improve education for the physical and social sciences, occupational choice and training, and planning and problem solving in government and industry.

Furthermore, links between the military and gaming are far from new: during World War II, the US army general staff were the first to use "wargames" and employed them to improve their image with the population. The advertising of one of the world's first commercial home video game consoles, the Odyssey by Magnavox (launched in the USA in 1972), emphasized the device's potential as an educational tool, and thus it might be considered one of the first serious video games. Later on, in 1973, educational games such as The Oregon Trail [4] and Lemonade Stand [5] were produced by the Minnesota Educational Computing Consortium (MECC). Lemonade Stand, which was created in 1973, focused on business management, while The Oregon Trail, produced in 1974, intended to teach users about American colonists and was very popular and is still popular today through mobile phones and Facebook [6]. It stands as an example of a successful serious game.

In 1981, a simulation tool known as The Bradley Trainer [7] was developed for the American army to train new recruits in how to operate a Bradley tank. This application was developed by a team from Atari and was based on the Battlezone arcade game, which is believed to be the first virtual reality arcade game. The years 1982 and 1983 saw the release of several arcade games such as Pole Position, as

Table 1: Milestones in the history of serious games.

Year	Serious game	Application
1970	Serious Games book by C. Abt	Academic book
1972	Magnavox Odyssey	Education
1973	The Oregon Trail	Education
1980	BattleZone	Training
1981	The Bradley Trainer	Training
1982/1983	Pole Position/Atari VCS 2600 console	Training
1996	Marine Doom	Military
2002	America's Army	Military
2003	DARWARS	Military
2005	VBS1	Military
2006	BiLAT	Interpersonal communication
2009	VBS2/Game After Ambush	Military
2012	X-Plane 10	Training

well as games for the Atari VCS 2600 console, such as Pepsi Invaders, which included elements of advertising (a type of application that today is known as an "advergame"). In 1996, the Marine Doom game [8] was used to train members of the US Marine Corps.

A first-person shooter game, named America's Army, was developed by the US army and distributed free of charge over the Internet in 2002. The game simulates military training exercises and combat missions, with the goal of promoting the American army and as a recruitment tool for young people between the ages of 16 and 24. Sawyer considered America's Army "the first successful and well-executed serious game that gained total public awareness" [6]. Other breakthrough games were DARWARS [9] introduced in 2003 and the VBS1 [10] in 2005.

In the last decade, serious games grew exponentially. A recent market study showed that the worldwide serious games market is worth 1.5 billion € in 2010, with a growth rate, over the last two years, nearly 100% per year [11]. For example, BiLAT, introduced and marketed in 2006, is an immersive learning environment that teaches the preparation, execution, and understanding of bilateral meetings in a cultural context [12]. The second generation of VBS1 was introduced in 2009 [13], with capabilities for training, simulation, and development. In March 2012, a new version of the flight simulator game X-Plane (X-Plane 10) was introduced to support various mobile platforms such as Android and webOS [14].

Some reviews were conducted in the serious games domain, most of them in specific areas of the domain such as education or physical well-being. In [15], a classification of serious games is proposed following what they call the G/P/S model. The authors observed that the existing classifications of serious games only use one or two criteria and that they are all based on the purpose served by the serious game and the market for which the game was designed. But they noted that the problem with the existing classifications is that they do not take into account the gameplay aspect of serious games. So they suggested a classification that uses three criteria: first, the gameplay which is based on the rules of the game and which was inspired from a classification of entertainment video games; second, the purpose of the game; and third, the scope which takes into account the market, the audience, and so forth. The authors use this classification for the educational field to help teachers find games suitable for education.

In [16], the authors emphasize the importance of a taxonomical approach to the scientific treatment of any subject, in particular the science of digital games with a focus on serious games. The taxonomy they propose is three-dimensional. The first dimension is that the digital game is computer software. The second dimension considers the genre of the game, whereas the third has to do with the interaction of players with the game. Another classification was proposed in [17], where the authors examined a database of serious games and defined four dimensions to classify serious games. The first one is the "primary educational content" delivered by the game, such as academic and social change and health. The second one is based on the "primary learning principles," such as practicing skills or problem solving. The third dimension is the age group targeted by the game, and the fourth one concerns the platform on which the game is played.

In contrast to existing classifications as discussed previously, in this work, we propose a multidimensional classification that examines serious games more closely by looking into the characteristics that are important in their design and that have the potential to make a significant difference in the success of a serious game. These criteria are based on conclusions drawn from the study of different serious games articles and applications, by analyzing their characteristics including the interaction style they offer to the player, the activity, the modalities, the environment, and the application area, as will be explained in a later section. Hence, we believe that the new classification we are proposing will allow a more detailed categorization and analysis of serious games.

The rest of this paper is organized as follows. Section 2 gives an overview of the growth of serious games over the years. Section 3 focuses on the terminology and contributes a definition of digital serious games. In Section 4, we suggest a taxonomy for digital serious games. We then review some relevant applications of serious games in different areas in

Section 5 and propose a classification of some of the reviewed applications based on the defined taxonomy. In Section 6, this paper provides guidelines drawn from the literature, for the design and development of successful serious games. Finally, Section 7 concludes with perspectives for future research.

2. Growth of Serious Games

2.1. Growth of Serious Games in the Research Field. The field of serious games has been growing rapidly for over a decade. To have a closer look at the trend of research in this domain, we carried out a survey of published articles related to serious games. We used online archives, covering the years from 1995 to 2013, of two major publishers: The Association for Computing Machinery (ACM) Digital Library and the Institute of Electrical and Electronics Engineers (IEEE) Xplore Digital Library. The obtained results are illustrated in the graph of Figure 1, which provides an estimation of the number of research articles in the field of serious games for the last two decades. We tried to eliminate double findings; that is, listing the same publication in both libraries was considered one hit only. The graph in Figure 1 reveals an exponential growth in the number of research papers published in the field, starting from the late 90s until 2013, which shows the growth in interest of the research community in serious games. This is accompanied by an important growth in industry as well, as shown in the next section. The estimated number of papers presented in Figure 1 was calculated based on the usage of the following keywords: "serious games," "serious game," "serious gaming," edutainment, gamification, and "serious play."

2.2. Growth of Serious Games in Industry. The graph in Figure 2 was drawn from data collected by [6] as well as our collection of industry-based serious games statistics from the Serious Games Association industry directory [18]. Figure 2 shows that, similarly to the research field, the growth in industry was exponential over the last decade. It is also estimated that the serious games market will keep growing quickly to reach a value of 10 billion Euros in 2015 [19].

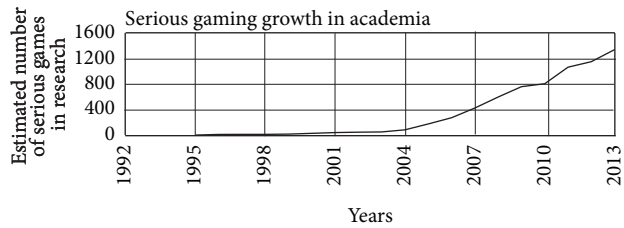

Figure 1: Serious games growth in the research field based on surveyed papers in ACM digital library and IEEE Xplore.

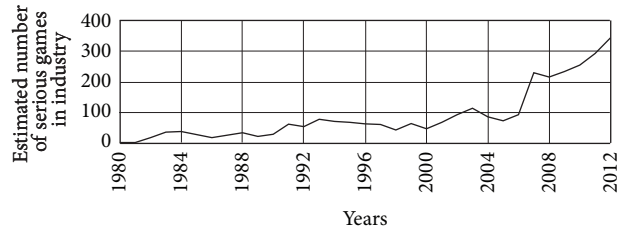

Figure 2: Serious games growth in industry.

3. Terminology and Definition

To start with, a game is defined as a physical and/or mental contest that is played according to specific rules, with the sole goal of amusing or entertaining the participant(s). On the other hand, a video game is a special type of games where the game is played with a computer according to certain rules with the goal of amusement, recreation, or winning a stake.

There are several perspectives of defining serious games as seen from the academia and the industry. For example, some industry figures believe a serious game must include a genuine entertainment element combined seemingly with a practical dimension [20]. Some researchers argue that all games have a serious purpose such as gambling, fortune telling, or politics. In this case, the term may be used to refer to any application produced using development software from the gaming industry, which means a majority of simulators would be considered serious games [21]. Others argue that a serious game is simply a computer game and that the classification is nothing more than a marketing technique [22].

Probably, the most common definition of serious games is "games that do not have entertainment, enjoyment, or fun as their primary purpose" [23]. Following this definition, serious games can be distinguished from video games by their design objectives in that serious games have a primary design objective other than entertainment. However, basing the definition of a serious game on its design objective causes a problem [24]. This problem is that if one wants to decide whether a specific game is a serious game or not, one would necessarily need access to the objectives or intentions of the game designer while designing that given game, which is far from practical. As put by the authors in [16] "... serious games are determined by some developers intention-a highly esoteric and impractical conceptualization. Developers' intentions are rarely accessible."

In this study, we contribute a definition of serious games following our review of the literature. We found that most definitions encountered either in research or industry agree that serious games include entertainment dimension [20, 24–26]. A serious game also has the potential to enhance the user's experience through multimodal interaction [27, 28]. This can be in different contexts such as education, training, health, or interpersonal communication. Most research agrees that digital serious games contain different media, which can be a combination of text, graphics [29], animations [30], audio [31], haptics [27, 32], and so forth. Furthermore, we believe that the "serious" term in serious games comes from their role of conveying some message or input, be it knowledge, skill, or in general some content to the player. This means that the player is exposed to an environment which delivers a content emanating from a know-how or experience. This experience is related to the specific context of the serious game such as

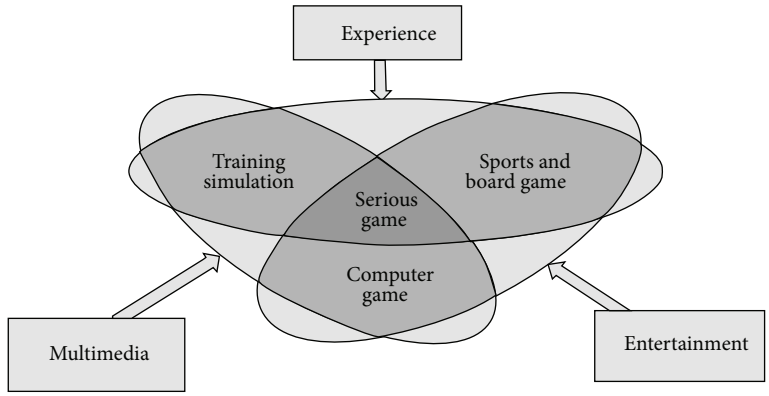

Figure 3: Definition of serious games.

well-being, education, and health. Hence, we define serious games as an application with three components: experience, entertainment, and multimedia, as shown in the diagram of Figure 3. The diagram demonstrates also the differences between serious games and several terminologies such as training simulation, computer game, and sports.

4. Taxonomy of Serious Games

Given the significant growth of serious games and even more future growth expected [19], we need to define a foundational taxonomy to classify and characterize the considerable work dedicated to this domain.

In an attempt to classify serious games, we try to define here the characteristics that are important in their design and that have the potential to make a significant difference in the success of a serious game. We thus suggest the following criteria that are based on information derived from the study of different articles and applications related to serious games.

4.1. Activity. The first characteristic that we define here is the type of activity performed by the player as required by the game. This is the function performed by the player as a response and/or input to the game. Activity types can be physical exertion, for example, in games for well-being such as in [33, 34] or games for health to fight childhood obesity [35]. The activity type can also be physiological such as in games for rehabilitation [36] or for the detection of some health conditions [37]. It can also be mental, for example, in games for education [29, 38], training [39], or interpersonal communication [12].

4.2. Modality. Another criterion that is of importance is the modality, which is here the channel by which information is communicated from the computer to the human(s) participating in the game. This characterizes the sensory modalities the player experiences in the game. The most common modalities include visual, auditory, and haptic. There are also some smell attempts that were contributed such as an application of using the sense of smell in therapy [40]. It is important to use modalities to the advantage of the game's purpose. Indeed, a study was conducted for UbiFit Garden and compared the performance of participants who had a display in their mobile phone's background that is visualized several times a day to the performance of those who used the same game but were not provided with such a display. The study showed that players who had the visible display were able to sustain their activity level, at the same time when those without the visible display experienced a decrease in their performance [29]. This study shows that using a display that provides visible feedback to players throughout the day can be a success factor of mobile serious games.

It is also important to include the right modalities in order to enhance the user's experience and thus to increase the successfulness of the game. For example, if we consider the auditory modality, an investigation was conducted in [31] in order to define properties that make a well-being serious game successful. One of the most important properties found was music incorporation in the game, which helps increase players motivation to exercise using the game in question. Also, integrating haptic feedback in serious games has, among others, the potential to enhance the learning experience through a tactile perception of objects [27] and to provide more realism in rehabilitation games for stroke patients [32].

4.3. Interaction Style. The interaction style defines whether the interaction of the player with the game is done using traditional interfaces such as keyboard, mouse, or Joystick or using some intelligent interfaces such as a brain interface, eye gaze, movement tracking, and tangible interfaces. Choosing the right interface during the serious game design may have an impact on the success of the game. For example, for some games, it is important to use intelligent interfaces instead of traditional interfaces. Such games include movement tracking such as the one provided by Microsoft Kinect or the use of a remote such as the Nintendo Wii remote which allows the player to feel more freedom and realism while playing the game. An example showing that using the right interface can be a determining factor in the success of serious games was explored in [41] using a system called Sensor Network for Active Play (SNAP). SNAP aims at getting players physically active and uses a set of sensors attached to the players limbs, which allow the system to make sure that the players are

moving their body as required by the game. This allows overcoming shortcomings in systems such as the Wii Fit where players can sit on a couch and move the Wii remote and still be able to get through the game without getting the desired physical exercise. So the interface used in a specific context may actually determine whether or not the game can serve its main goal and how well it serves it.

Additionally, for some games, it would not be useful to use traditional interfaces, for example, if the game needs as input a kind of biological data such as heartbeat rate, which is in this case collected from the player's body by means of biosensors and sent directly to the game without the user's interference. In other areas, it is actually critical to integrate the right interface in the game, as is the case, for example, in the rehabilitation domain. Indeed, a game for stroke patient seeking help with rehabilitation process will not be useful unless the appropriate interface between the user and the game is chosen carefully following the specific need of the targeted users [42].

4.4. Environment. This criterion defines the environment of the digital game and can be a combination of several criteria.

(i) 2D/3D: the environment of the serious game can be either 2D (two-dimensional) or 3D (three-dimensional) or a combination of the two.

(ii) Virtual or mixed reality environment: virtual reality refers to a completely synthetic world. It is a computer-generated immersive environment that can either represent the real world or be purely imaginative. Virtual reality is widely used in serious games such as in [29, 31, 39]. A mixed reality, such as used in [35], includes both augmented reality and augmented virtuality. It refers to an environment that merges real and digital worlds, allowing objects from each world to interact in real time.

(iii) Location awareness: it depends on whether or not the game allows the determination of the player's current location.

(iv) Mobility: it determines whether the game is mobile or not.

(v) Online: it determines if the game can be played over a computer network, usually the Internet.

(vi) Social presence: it depends on whether the game is single or multiplayer. This can be an important criterion to be taken into consideration, as shown in [43], where some research was conducted specifically for exercise games and concluded that multiplayer collaborative exercise games are more motivating and engaging than single-player exercise games.

4.5. Application Area. The application area refers to the different applications domains relevant to serious games. There are many possible application areas. If we consider the importance of areas in terms of their share in the market, educational games were clearly dominant up to 2002 with a market share of about 66% [6]. However, this market dominance decreased to about 26% from 2002 to 2009, while games for advertising increased from about 11% to 31% in the same period of time [6]. According to these statistics, education and advertising are dominant, occupying about 57% of the whole serious games market, while the rest of it is shared between other areas. These include, among others, health care, well-being, cultural heritage, and interpersonal communication.

Based on the set of characteristics defined above, we propose the following taxonomy for serious games, as shown in Figure 4.

5. Review of Serious Games Applications in Multiple Areas

Many serious games were proposed in research. This section reviews some examples of relevant serious games applications that have recently been developed in different domains, including education, training, well-being, advertisement, cultural heritage, interpersonal communication, and health care. In each application area, we tried to cover a variety of available serious games examples. We first give the reader an overview of the game's main goal and describe briefly how the game goes about serving its purpose, and then we use some of the games discussed here to propose a classification of serious games. In this classification, the applications used are described in detail following each of the criteria of the taxonomy that we defined previously, to allow for the comparison of some existing serious games and to contrast them in terms of their key characteristics. This has the potential to help bring to light where research in this domain is missing and direct new efforts in the right way. The description of games in this section, as well as the classification that will follow, also serves to give the reader an idea of how new technology can be applied in different serious game areas in order to achieve their goal in a more effective way.

5.1. Education and Training. Many research contributions are directed towards taking advantage of the success of video games and using them to benefit the educational domain. The addictive nature of game play and obsession of the players with digital games is attempted to be used to facilitate the learning process of players. As a growing number of young people spend hours playing video games, Quest to Learn, a middle school that opened in September 2009 in New York City, is based completely on a game-like learning model. In this school, students spend their day learning by playing games and designing them.

Some educational games are developed for classroom use, and the areas taught by them can vary widely. An example of such game is Skills Arena [38] that was designed specifically for classroom use. Skills Arena uses Nintendo Gameboy and teaches students arithmetic skills at varying levels of difficulty. A study was conducted involving elementary school students and concluded that playing a technology-based game increased students' performance in mathematics. Another example of educational games used

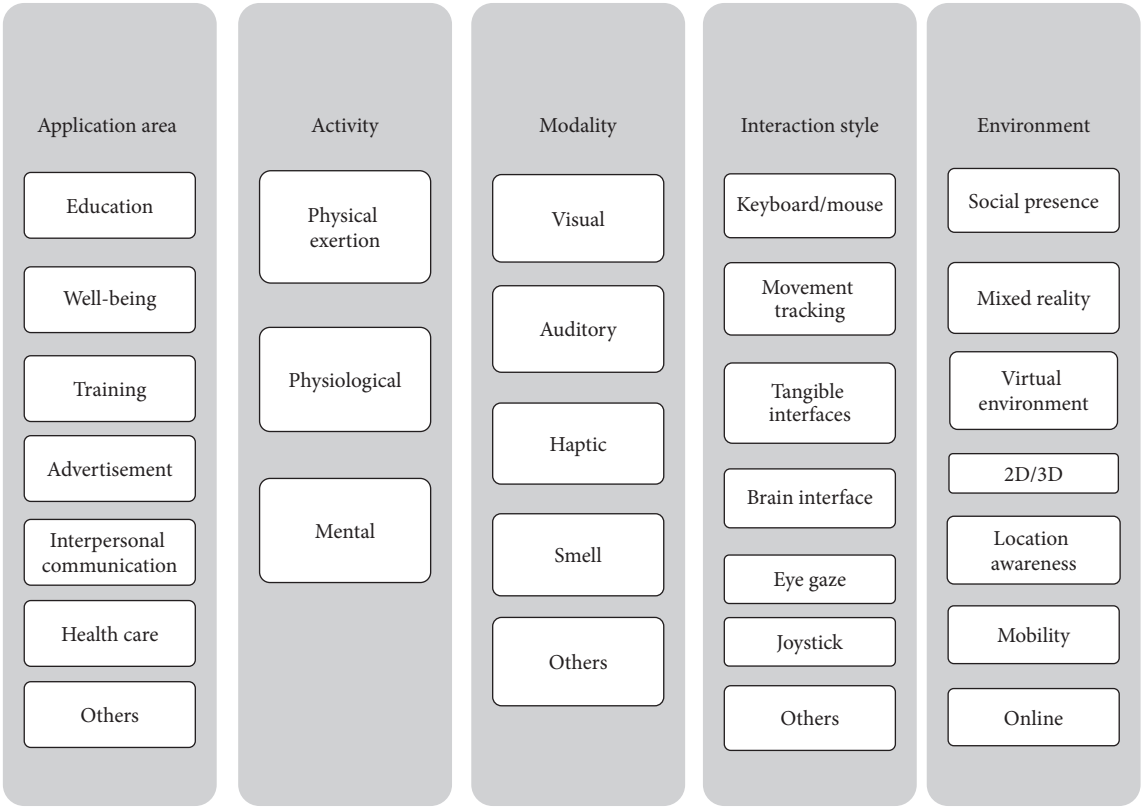

Figure 4: Taxonomy of serious games.

in the classroom in a case study is Making History [44]. It was used to evaluate its effectiveness in teaching high school students about World War II. This case study was conducted for a history class where the teacher used the game for this particular subject instead of traditional learning methods. The study resulted in the students being more interactive and more engaged in the learning process [44]. Another educational game can be used by computer science teachers to teach computer programming skills to university students [45]. It is a multiplayer strategy game with the objective to help students overcome the many difficulties they face while learning programming. Also, in the context of classroom use of serious games, the research in [46] is focused on the design of tools that allow teachers who have no knowledge of games programming to build educational games for use in their classroom teaching.

Other educational games are rather used for independent learning. A good example is in the area of language acquisition. For example, Lost in the Middle Kingdom [47] helps the players in learning a second language. Other areas covered in the educational domain are social awareness and teaching players about poverty. In this area, the 3rd World Farmer [48] is a simulation and management game, whose goal is to sensibilize players to the hardships of maintaining a farm in developing countries. Here, another example to consider is IBM CityOne or IBM INNOV8 [49], a city-building simulation game introduced in 2010, to educate players about problems facing today's cities related to transportation, energy infrastructure, and water management in order to design smarter cities that can sustain and encourage the growth of a prosperous population in the future. Clean World is a 3D game that also educates about today's environmental challenges [50]. It was developed using a design methodology that aims at prioritizing the fun aspect of the game, by using different learning mechanisms that are related to the game but that do not directly interfere with the main gameplay. In [51], a model of assessment of the player's motivation was proposed. It was used in the objective of adapting the educational game to the players' abilities and to keep the challenge element balanced depending on the assessment performed by the game engine.

A game using the haptic technology to teach players about artefacts is Roma Nova [27]. It is a multimodal game that uses an affordable off-the-shelf haptic device, Novint Falcon, which allows players to feel properties of the 3D game environment such as texture and shapes of artefacts. Some educational games efforts are also directed to the medical domain. A serious game for training was designed for surgery residents, with the purpose to train and educate them on the total knee replacement procedure [39]. The game uses a background sound captured during a real knee replacement surgery for more realism.

Another interesting type of serious games to consider here is data games, which are games that allow learning from and exploration of real world data. An example of such games is Foldit [52], a puzzle game that allows players to learn about

proteins and contribute to scientific research with innovative ways of protein folding.

5.2. Well-Being. A sedentary lifestyle is a well-known contributing factor not only to obesity, but also to many diseases such as diabetes and heart disease. Increasing physical activity works as prevention against these problems. Serious games for well-being aim at motivating players to be physically active by the means of an entertaining and engaging game play. The authors in [53] explored how the intention element of players may affect how they will benefit from the exercise game. They used a popular game for Xbox Kinect and found that players who were primed with the intention to use the game primarily for health benefits and who received health feedback while playing the game ended up using the exercise game for longer periods of time than other players who were not.

Another example of an exercise game is a mobile game, Heartlands where players walk around an area of their choice, wearing a heart-rate monitor and carrying a Pocket PC with GPS. A landscape is built on the Pocket PC screen as the player moves around. The resulting landscape is a representation of the player's heart performance as well as his location [54]. Another mobile fitness game also uses a wearable heart-rate monitor and a GPS device, called Monster and Gold, and includes a set of rules to motivate players to jog outdoors at their optimal heart-rate level [33]. UbiFit Garden is another mobile application that turns the background screen of a mobile phone into a virtual garden. This garden flourishes following the amount of daily physical activity of the individual, which is collected using a worn fitness device. A three-month experiment concluded that the background display had a positive effect on participants and helped them sustain their level of activity [29] during the winter months when the physical activity tends to decrease [55]. Life is a Village is an example of how two players with different fitness levels can collaborate to play an exercise game at the same time [31].

In another multiplayer exergame, Fish'n'Steps, players wear a pedometer, which provides the account of their daily footsteps. The game can also be played both competitively and cooperatively as a way to further motivate the players. A fourteen-week study showed that participants developed healthier daily activity patterns [30]. Sensor Network for Active Play (SNAP) is an exergame system where players have sensors attached to different parts of their body to make sure their whole body is moving. In a game using this system, players have to reproduce a set of dance positions, and their performance is then evaluated by the sensor network. A comparative study was carried out and showed that SNAP outperformed some commercial games such as the Wii in terms of energy expenditure as well as heart-rate adjustment [41]. The study also showed that the fun factor was rated high. The authors in [56] designed a cycling-based game for children with cerebral palsy. Based on a year-long study, they found that, despite their motor disabilities, these children were able to enjoy and benefit from a fast-paced action exercise game.

5.3. Advertisement. Serious games designed for advertising aim at promoting a particular brand, product, or a service to the users while they play a game, a term commonly known as advergames [20]. Examples of commercial advergames include advergames funded by Pepsi, 7 Up, NFL, Formula One, and Burger King [57]. Even though America's Army game is intended mainly for military training, it also intends to boost recruitment for the United States Army and thus can be considered an advergame [20].

The authors in [58] found that 35% of players could recall advertised brands in a controlled study of car racing games, thus promoting adverting within the game itself. For instance, an Adidas billboard is displayed in the foreground of the 2011 video game FIFA International Soccer (also, the electronic board that appears with every goal scored sometimes reads "Panasonic").

5.4. Cultural Heritage. Advances in gaming technologies allow the real-time interactive visualization/simulation of realistic virtual heritage scenarios, such as reconstructions of ancient sites and virtual museums, while using basic consumer machines (such as mobile phones or personal computers). Although games for cultural heritage provide some cultural education, they differ from other games for education in that they aim at supporting the preservation of artifacts and their reproduction. They also promote cultural awareness and allow for the appreciation of artifacts.

This section provides an overview of recent work in cultural heritage, which can be classified into three types of applications: reconstruction of history, virtual museums, and cultural demonstrations. The most popular commercial examples of serious games for cultural heritage come from the nineties "Cultural Entertainment" wave, including The Amazon Trail from Minnesota Educational Computing Consortium (MECC) in 1993, Museum Madness from Appaloosa Interactive (formerly Novotrade International) in 1994, Versailles 1685, Egypt 1156 BC Tomb of the pharaoh, and China the Forbidden City by Cryo Interactive in 1997, 1997, and 1998, respectively, Byzantine: The Betrayal by Discovery Channel Multimedia in 1997, Pilgrim Faith as a Weapon by Axel Tribe in 1998, Vikings by Index+ in 1998, and Rome: Caesar's Will by Montparnasse Multimedia in 2000.

Cultural demonstrations educate people about tradition, beliefs, and social values via techniques such as folktales and storytelling. For instance, the authors in [59] presented the design and development of a mobile game, named m-MyTale, based on popular Malaysian folktale stories (such as "The Princess of Mount Ledang") to promote children education about their culture and heritage. However, no evaluation of the game was presented in the paper. Another interesting work involves teaching Thai sword dance as a presword fighting match tradition [60]. The game is designed by combining acquired animations with gesture recognition (supported by the Nintendo Wii controller).

An online multiplayer serious game called ThIATRO that helps students learn art history is proposed in [61]. The game is part of a big project "The Virtual 3D Social Experience Museum" that seeks to develop an instrument to support

the bidirectional interaction between museums and visitors using Web3D. Another game introduced by [62] aims at improving cultural heritage awareness during the museum visit. The game, called Solis Curse, uses multimodal interaction (audio, video, 3D graphics, etc.) and presents a series of questions with progressional levels of difficulty where the player score is calculated accordingly and compared with a global ranking ladder.

5.5. Interpersonal Communication. Good communication skills are very important in all aspects of life. We communicate all the time, and the efficiency with which we communicate highly influences our success whether it is in personal relationships or professional career. A number of cultural learning systems that take advantage of serious games can be found in the literature. The Tactical Language and Culture Training systems provide a mission practice environment that enable learners to explore a virtual town while speaking to locals in Arabic, learn how to make culturally appropriate gestures, and accomplish goals such as getting the names of contacts and/or directions [63]. VECTOR is another cultural learning system that provides similar training in foreign town but uses English language and American culture [64].

The Enhanced Learning Environments with Creative Technologies for Bilateral negotiations (BiLAT) is a serious gaming immersive learning environment that teaches the preparation, execution, and comprehension of bilateral meetings in a cultural context [12]. An intelligent tutoring system that focuses on face-to-face meetings between learners and virtual characters to teach cultural social conventions is introduced in [65]. StoreWorld is an educational game that teaches students business principles and explores how social interaction can improve simulation in business games [66]. Another management game facilitating interpersonal communication is SimParc [67]. It is a game prototype designed to support intercultural participatory management of protected areas in order to promote biodiversity conversation and social inclusion. DeLearyous is a serious game that focuses on the improvement of interpersonal communication skills [68]. The game is an attempt to substitute for personal coaching which can be costly. Furthermore, using a virtual environment to work on communication skills has the advantage of allowing players to safely make mistakes, without fearing the consequences.

5.6. Biomedical and Health Care. We limit health care applications to a simple definition that requires being free from illness or injury (note that a broader definition includes well-being application that was discussed earlier in this section). The main goal of games for health care is to pass on knowledge and/or skill to players and to serve a medical purpose by simulating a situation to avoid risk, safety, budget, and so forth. Accordingly, we classify serious games for health care into four categories: (1) health monitoring, (2) detection and treatment, (3) therapeutic education and prevention, and finally (4) rehabilitation; we provide a summary of related work in each of these classes. Comprehensive reviews for serious games in health care can be found in [69, 70].

Several serious games for health monitoring can be found in the literature. The Home Automated Telemanagement (HAT) system is proposed in [71] to help patients with congestive heart failure (CHF) monitor their symptoms, weight changes, and quality of life while teaching the patient the characteristics of their disease. The system runs on the Nintendo Wii console and requires Internet connection to execute. A similar medical diagnostic gaming system, which is used to gather information about the patient's condition in a causal, nonintrusive manner that is relaxing for the patient, is introduced in [72]. Another u-health monitoring system with a Nintendo DS is presented in [73]. The system displays the biosignals onto a monitor of personal computer and LCD of a Nintendo DS using a biosignal measurement device.

The research and development related to the detection and treatment of various health conditions using serious games have grown significantly in the last few years. 21 Tally is a collection of 2D games used to detect divided attention unobtrusively, using a game designed to force players to attend to different dimensions simultaneously in order to succeed [37]. Two EEG-based concentration games, namely, Brain Chi (2D) and Dancing Robot (3D), were developed for concentration level control [74]. Match-3 is a serious game designed to combat childhood obesity using the Wii-mote [35]. Other examples include a medical gaming environment for diagnosis and management of Parkinson's disease using a Novint falcon haptic interface [75] and a 3D game that can analyze the behaviour and promote certain social skills (such as conversation and negotiation) of people with neurological development disabilities [76].

The area of therapeutic education and prevention also benefits from the use of serious games for health. Therapeutic education games can educate either patients themselves or the people around them about therapy for a specific illness. For example, Elude [77] is a game that targets relatives or friends of patients suffering from depression. This game is designed to inform them about this illness and allows them to be involved in the therapy process of the patient.

One of the health areas where serious games can have a pronounced positive impact is rehabilitation. The National Institute of Neurological Disorders and Stroke (NINDS) estimates that neurological disorders affect about 50 million people every year in USA alone [78]. Many patients afflicted by such disorders need rehabilitation to help them regain control over their motor skills. Using games for rehabilitation has been proved to be a good solution to the lack of motivation that results from the repetitiveness of exercises in traditional physical therapies [79]. The Rehabilitation Gaming System (RGS) [36] was designed in this context, to help with the recovery of patients who suffer from brain legions. The RGS uses data gloves to detect finger movement, as well as a video camera to follow the movements of the wrists and elbows, and the system can be used by patients either in clinic or at home. A 12-week study of the use of games in falls rehabilitation at home concluded that games were used with more consistency comparing to conventional rehabilitation [80].

5.7. Putting It Together. Table 2 suggests a classification of examples of serious games examined earlier in this section.

Table 2: Classification of serious games.

Game	Application area	Activity	Modality	Interaction style	Environment					
					Real/virtual/mixed	Mobility	Single/multiplayer	2D/3D	Location awareness	Online
Heartlands	Well-being	Physical exertion	Audio/visual	Pocket PC and heart-rate monitor	Virtual	Yes	Single- and multiplayer	2D	Yes	No
Life is a Village		Physical exertion	Audio/visual	Exercise bike and Wii remote	Virtual	No	Single- and multiplayer	3D	No	No
Monster and Gold		Physical exertion	Audio/visual	Mobile phone and heart-rate monitor	Virtual	Yes	Single	2D	Yes	No
Sensor Network for Active Play (SNAP)		Physical exertion	Audio/visual	Sensors (accelerometers)	Virtual	No	Single- and multiplayer	—	No	No
Fish "n" Steps		Physical exertion	Visual	Pedometer	Virtual	No	Single- and multiplayer	2D	No	—
UbiFit Garden		Physical exertion	Visual	Mobile phone and fitness device	Virtual	Yes	Single	2D	No	No
Rehabilitation Gaming System	Health care	Physiological	Audio/visual	Data gloves and camera	Virtual	No	Single	3D	No	No
HAT		Mental/physical	Audio/visual	Nintendo Wii	Virtual	Yes	Single	3D	No	No
21 Tally		Mental/physical	Audio/visual	Biofeedback sensors	Virtual	Yes	Single	3D	No	No
Match-3		Physical exertion	Audio/visual	Wii-mote	Mixed	No	Single	3D	No	No
Making History	Education and cultural heritage	Mental	Audio/visual	Traditional interfaces	Virtual	No	Single- and multiplayer	3D	No	Yes
Roma Nova		Mental	Audio visual and haptic	Traditional interfaces and haptic device	Virtual	No	Single	3D	No	Yes
Ayiti: The Cost of Life		Mental	Audio/visual	Traditional interfaces	Virtual	No	Single	2D	No	Yes
3rd World Farmer		Mental	Audio visual	Traditional interfaces	Virtual	No	Single	2D	No	Yes
Lost in the Middle Kingdom		Mental	Audio/visual	Traditional interfaces	Virtual	No	Single	3D	No	No
Skills Arena		Mental	Audio/visual	Gameboy	Virtual	Yes	Single	2D	No	No
IBM CityOne Game		Mental	Audio/visual	Traditional interfaces	Virtual	No	Single- and multiplayer	2D	Yes	Yes

Table 2: Continued.

Game	Application area	Activity	Modality	Interaction style	Environment					
					Real/virtual/mixed	Mobility	Single/multiplayer	2D/3D	Location awareness	Online
DeLearyous	Interpersonal communication	Mental	Audio/visual	Traditional interfaces	Virtual	No	Single	3D	No	No
BiLAT		Mental	Audio/visual	Traditional interfaces	Virtual	No	Single	2D	No	Yes
VECTOR		Mental	Audio/visual	Traditional interfaces	Mixed	No	Single	2D	Yes	Yes
StoreWorld		Mental	Audio/visual	Traditional interfaces	Virtual	Yes	Multiplayer	2D	No	Yes
SimParc		Mental	Audio/visual	Traditional interfaces	Virtual	Yes	Multiplayer	3D	Yes	No

The classification is done following the taxonomy proposed in Figure 4 which is based on the set of criteria discussed in the previous section.

6. Success Factors in Serious Games Design and Development

In the following, we present some success factors drawn from the literature review that compile together a number of research efforts, and we recommend that they be considered for the design and development of successful serious games.

An investigation was conducted in [31] in order to define properties that make a well-being serious game successful. One of the suggested properties is music incorporation in the game, which will help motivate players to exercise using the game in question. The focus was also made on the importance of providing guidance to players within the game. We can generalize this last requirement to different areas of serious games such as education, interpersonal communication, or health care, since providing guidance to players especially in the early stages of playing the game provides them with the necessary knowledge and prevents them from feeling "lost" or confused.

Another important success factor is avoiding negative consequences in the game, as results of the player's low performance. In Fish'n'Steps [30], negative outcome of the player not performing enough physical exercise includes their virtual pet fish displaying sad emotions. This negative effect did not encourage all players to perform better. It actually discouraged some of them to interact with the game and to check the display on the screen in order to avoid visualizing the crying pet fish [30]. This conclusion, although drawn from an experience that uses an exercise game, could also be recommended for serious games in general. This is because it is related to the psychological effect that negative outcome had on players, rather than the physical aspect of playing the exercise game.

A study was conducted for UbiFit Garden and compared the performance of participants who had a display on their mobile phone that is visualized several times a day and performance of those who were not provided with such a display. The study showed that players who had the visible display were able to sustain their activity level at the same time when those without the visible display experienced a decrease in their performance [29]. This study shows that using a display that is visible to players throughout the day can be a success factor of mobile serious games.

Another guideline was drawn from a research conducted in [43], which concluded that multiplayer collaborative exercise games are more motivating and engaging than single-player exercise games. The study did not find any differences in players' motivation when the game was played in distributed or colocated environments. This suggests that the game can be played collaboratively online without diminishing the enjoyment of the game. We have to note that the study was conducted for collaborative rather than competitive multiplayer games. We suggest, in the design of serious games, providing an option for the game to possibly be used in a collaborative environment, given the important role that this can have in increasing players' motivation.

The next guideline is specific to educational games that are designed for classroom use. It is to be taken into consideration when designing such games that conventional teachers are concerned about the curriculum and are also on a limited time schedule. Educational games that are based on the curriculum have higher chances to be accepted and integrated in the class program by teachers [81].

In a 6-week study performed in [82] using a social game, it is shown that offering challenges in the game was found to be of significant importance to children. The study results showed that challenge is the game element that increased children's immersion the most. This property can be used for serious games design by trying to keep the challenges levels neither too high which would result in demotivation nor too low which would lead to perceiving the game as uninteresting. Keeping the challenges at the right level is key in keeping the players interest in the game.

Another set of design guidelines is drawn from [83], where the link is made between successful commercial games and good accepted pedagogical theory. The focus in [83] is made on educational games, and it is suggested that, for them to be successful, their design has to take into consideration sound instructional models as already done, intentionally or not, in successful commercial games. The instructional model that was focused on in [83] is the nine events of instruction by Gagné et al. [84]. These are briefly the following.

(1) Gain attention.

(2) Inform learners of the objective.

(3) Stimulate recall of prior learning.

(4) Present stimulus material.

(5) Provide learning guidance.

(6) Elicit performance.

(7) Provide feedback.

(8) Assess performance.

(9) Enhance retention and transfer.

For more details on each of these steps, we refer the reader to [84]. If the use of such steps has led to success in commercial games, then making use of them in serious games seems like a promising approach towards serious games effectiveness.

7. Conclusions and Research Perspectives

The field of serious games has been exponentially growing during the last decade as discussed in the first section of this paper. Many different definitions of a serious game were proposed and argued in literature. We have discussed some of the existing ones, and then, based on our review of the serious games literature, we suggested a definition that is open to discussion and improvement.

With the growth of serious games, a need emerged for a taxonomy for a better foundation of the considerable and growing effort being put into the field. In this paper, we

have contributed a taxonomy and then provided a review of relevant serious game applications related to various domains including education, well-being, advertising, cultural heritage, interpersonal communication, and health care. We also used some of the reviewed serious game applications from the literature to propose a classification.

Serious games have huge potential as a means of improving achievements in a variety of domains including education, advertising, and health care; however, not all of them are successful. For serious games to serve their purpose, special attention should be paid during their design and development. For this purpose, we have drawn guidelines from literature for serious game design and development. In this context, it is also important to discuss critical factors that will be key in accelerating the move of serious games towards mass adoption. Some of these factors are the following.

(i) User-centred software engineering: an important element for the success of the serious games industry is the perspective that the designers contribute to the development teams. Indeed, in order to develop an effective serious game, in-depth understanding of the experience that the end users will get while playing the game will provide the development teams with a sensibility that is a must for the success of the technology.

(ii) Multimodal serious games: in order for a game in general and a serious game in particular to be convincing to the user, multiple modalities should be incorporated. For example, integrating the haptic technology in a serious game can add a hands-on element to the learning experience in educational games, as well as providing tactile and force feedback in rehabilitation games in the health care domain [32]. However, some researchers have already proved that in some cases multimodal interaction might be distracting to the user, and thus the overall performance drops. Such cases need to be investigated and clearly identified.

(iii) Social well-being: stimulating a feeling of virtual presence or connectedness that can contribute to social well-being in real life is a key success factor for serious games. In this context, the development of novel forms of social communication would promote serious games.

(iv) Adaptive gaming: a serious game should adapt to a particular player's capabilities, needs, and interests. For instance, the game contents may be adapted according to the player age group, gender, profession, and physical and psychological state among others.

(v) Standardization of evaluation: in order for the serious game domain to acquire higher credibility by the general public, heuristic evaluation standards must turn into a reality. Nowadays, there is a lack of standardized means to indicate whether a game is indeed "serious" or how "serious" a game is. If serious games are made entertaining and fun, this could facilitate their adoption by children and adults alike. So the question that we think should be addressed by the research community is, how can we model entertainment from a user experience perspective? What are the elements that make up "fun" design and how can the effectiveness of this design be measured? Currently, many developers/researchers are proposing various types of serious games. Some of these are powerful and provide value to the player, but, unfortunately, many are boring and therefore useless. Formal evaluation methods are certainly welcome not only by the research community, but also by potential users of serious games. However, various challenges arise and have to be overcome for an effective evaluation. For example, motivation of players evaluated in an artificial environment may not be accurate. Motivation also needs to be measured in the long run, as some games may seem as attractive in the beginning, but if the player loses interest in the short term, there will not be any real benefit from the game for the player. Another difficulty arises when evaluating a game for clinical use or for classroom use which can be hard to access. But evaluation remains definitely essential both for measuring the effectiveness of a given serious game and for allowing improvement of serious games by pointing out particular weaknesses. A performance metrics that defines how serious games are evaluated is definitely welcomed by the research community.

(vi) Sensory-based simulations: serious games can be created based on real world sensory data in order to accurately reconstruct real world scene. To get to this point, methods and techniques are required to transform and process raw sensory data to create fully functional game worlds. Other sensory information can be read about the human physiology and integrated into the gaming environment.

Several researchers have investigated the potential of tangible and/or intelligent interfaces as means of interaction for serious games. There is a need for more natural interfaces between the user and the game environment. For example, using a real physical cup or a stress ball or a dumbell as a game controller would benefit serious game design and development. More research in this area is needed.

For a serious game to be successful, an important element is for the game designer to achieve a balance between the fun element and the main purpose of the game which is obviously not entertainment. This means that the entertainment element of the game should not be sacrificed in an attempt to reach the main goal of the game, whether the latter is teaching or improving a health condition and so forth. It may be tempting and even sound logical to give priority to the serious element of the game over the stimulation and engagement that the game is supposed to provide. However, the enjoyment of the game is the very means by which the goal can be reached. Thus, the game, serious as it may be, should be kept enjoyable, or the serious goal would not be reached even though it was given the highest attention in the development of the game. How this balance can be achieved is an area open to research.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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