Serious games for e-health care

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1 Introduction

In this paper, we survey the serious games that are related to health and classify them with respect to different aspects. Not only games that have been described and evaluated in peer-reviewed publications are presented in this article but the scope of the survey also includes: 1) the commercial games (consoles and PCs) 2) online games 3) games and application on mobile platforms 4) games running on specialized platforms in clinics, hospitals and patients homes.

We begin with reviews of important concepts: section 1.1 provides an introduction of serious games, and section 1.2 describes health. Section 1.3 describes the intersection of the two fields, and provides a review on previous surveys. Section 2 details the different ways in which serious games in health can be classified, while section 3 contains a comprehensive list of games. A summary of their main characteristics, a comparison table, graphs and a discussion of the results is present in section 4. Finally, section 5 concludes the paper.

1.1 Serious games

Today, the term serious game is becoming more and more popular even though there is currently no single definition of the concept. Serious games are defined in

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contraposition to entertainment games. They inherit gameplay characteristics from entertainment games, but the main focus may be learning or training, and the lessons learnt are expected to be used in real-life work environments. Serious games are present in many areas of knowledge, including defense, manufacturing, education and medicine, among others.

According to Navarro[38], serious games is an emerging technology growing in importance for specialized training, taking advantage of 3D games and game engines in order to improve the realistic experience of users. We propose the characterization of serious games by using the following main components: rules and gameplay, challenges, interaction modes and goals. The gameplay is the pattern defined through the game rules which connects the player and the game. The goals may be explicit (stated as game objectives) or implicit. Implicit goals may include increasing skills and abilities, gaining knowledge or acquiring experience (Fig. 1).

1.2 Importance of health

The World Health Organization (WHO) [1] defined health in its broader sense as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity." Other definitions simply require being free from illness or injury [57].

If we use the stricter definition, we may only consider games dealing with the different phases of illness development, both doctor training and patient familiarization with his illness. However, the use of the WHO definition allows us to consider a third variety of games which has had a big success recently: games dealing with healthy habits such as exercise (including dancing and fitness games), so we shall use this broader definition in this paper.

In Maslow's hierachy of needs [33] , health is represented in the second lowest level, after basic needs required for life are fulfilled. Health is then a very basic need, and maintaining health should therefore be a priority. Additionally, the desirable human characteristics located in higher levels of Maslow's pyramid which are needed for a functioning, peaceful society are negatively impacted by lack of health in the population. From the reasons stated above, Healthcare is one of the main issues that affects people the most in every stage of life (from infancy to old age). Many re-
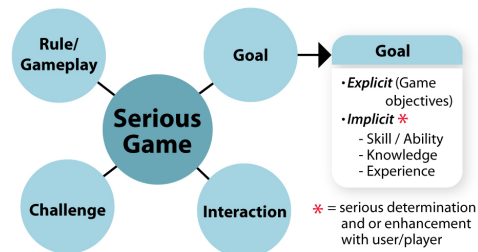
Fig. 1 The components of Serious Games

searches [29] [20] have shown the need of highly trained and educated health care professionals to avoid medical errors, and the use of serious games in health can provide an additional mean to increase interest in training, education and evaluation of their performance, as we will see in the next section.

1.3 The use of serious games to promote health

Repetitive tasks are needed in many cases to treat patients, but patient boredom has a negative impact on the patient's willingness to continue the treatment. The use of tailored games to replace these tasks therefore has good results.

Additionally, since the recent explosion of videogames, which now are used in two thirds of households by people of all ages [40], patients can feel more at ease and enjoy their treatment performing an activity they like.

Since 2002 [42] many serious games in the field of e-health have been developed, dealing with a wide variety of aspects of surgeon training, radiology operation, Cardiopulmonary Resuscitation (CPR) and patient care, among others. Games aimed at patients have also been developed.

The previous surveys of serious games are described next; Ricardo and Rafael [32] present the state of adaptivity in general games and simulations focusing on the purposes, targets, and methods from both academia and industry. N.A. Bartolome et.al. [7] present a systematic review of 21 serious games for health and education described at scientific papers written in English from 2003 to 2011 and projects from the 7th Framework Program. Pamela M. Kato [27] summarize the scientific literature of commercially available and tailor-made games used for education and training with patients and medical students and doctors. The classification is based on diseases. Paula et al. [41] propose a classification designed to properly distinguish and compare eight Serious Games for Rehabilitation systems with respect to their fundamental characteristics. They also describe a particular Serious Game for Rehabilitation, RehaCom, as a case study. Carolyn et al. [59] explore the use of games for children with long term treatment regimes, where motivation for compliance is a key factor in the success of the treatment.

2 Classification of surveyed serious games for health

There are many interesting criteria to classify serious games in health. In this section, we describe these criteria in detail (Fig. 2).
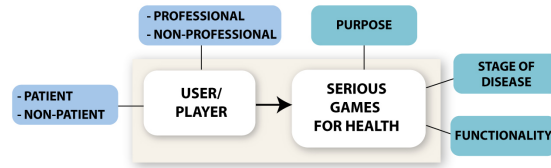
Fig. 2 Classification of Serious Games for Health

2.1 Classification by main purpose

There are three main purposes in serious games for health:

- The main purpose is entertainment but there is a need to move some parts of the body so the wellness is gotten as a bonus, such as dance dance revolution (DDR) [60] which is the pioneering series of the rhythm and dance genre in video games. The exercise (commercial) games became famous since Wii [39] was released by Nintendo on November 19, 2006. The motion controlled over the avatar by various accessories inspired people to exercise with the video games.
- The main goal is Health but the game is used as a tool to pass on knowledge and / or skills. To use the capability of the game engine, various serious health contents are conveyed to players; for example Fatworld [49], Re-Mission [53], Air Medic Sky 1 [54] and many other games shown in section 3 (Review Studies).
- Serious use in health and medical purpose but with a need to simulate the situation to avoid / concern risk, safety, budget, etc. Most of the games in this category are simulation games with use in health and medical field such as Virtual Dental Implant Training Simulation Program [9] [16], EMSAVE ("Emergency Medical Services for the disAbled" Virtual Environment) [55] [22], Olive: 3D Hospital Training [48] [44], etc.

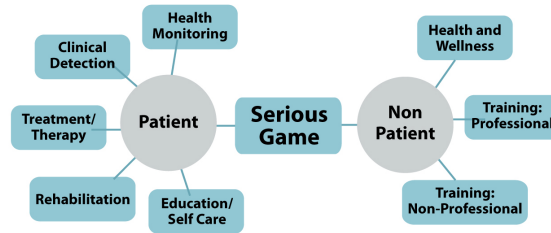## 2.2 Classification by player (patient/non-patient)

2.2.1 Patient

To classify the health objectives related to stage of disease

- Health monitoring
- Detection
- Treatment
- Rehabilitation
- Education for self/directed care

2.2.2 Non-patient

- **Health and wellness** focuses more on lifestyle issues and their relationships with functional health, data from the Alameda County Study [24] suggested that people can improve their health via 1) exercise, 2) enough sleep, 3) maintaining a healthy body weight, 4) limiting alcohol use, and 5) avoiding smoking.
- **Training and Simulation** for both professional and non-professional.

Fig. 3 Classification of Serious Games for Health by player

Patient	
Monitoring	CHF telemanagement systems [18], Healthcare monitoring [17] and The u-health monitoring system [31]
Detection	Unobtrusive Health [34] and EEG-Based Serious Games [58]
Treatment	Match-3 [46], Diagnosis and Management of Parkinson [6] and Social skills [8]
Rehabilitation	Neuropsychological Rehabilitation [21], Chronic Pain Rehabilitation [47], Upper Limb Rehabilitation Following Stroke [10] and After Parkinsons Disease [52]
Education	Re-Mission [53]

Table 1 Classification of Serious game for Health (Patient)

Non-Patient	
Health and Wellness	A Sensory Gate-Ball Game [28], Dancing in the Streets(DITS) [15], Fitness Adventure [30], Virku [56] and MoFun Circus [13]
Training: Professional	HumanSim(Preview) [5], Virtual Dental Implant Training Simulation Program[9] [16], Nursing and Midwifery [50], Pulse(The Virtual Clinical Learning Lab) [9] [3], EMSAVE (Emergency Medical Services for the disAbled) [55] [22], MUVE Market Virtual Patient CareSimulation Lab [37], Olive: 3D Hospital Training [48] [44],Game-based learning for Virtual Patients [45], Nurse education [4], Virtual Patient [2], Medical Simulation Training Program(JDoc) [51], VI-MED [36], Sabri2010 [43] and Air Medic Sky 1 [54]
Training: Non-professional	Terveellinen Ateria[26], MC Urho[12], Valion Energiasummaaja[11], Fatworld[49] and The Food Detectives Fight BAC! game[19]

Table 2 Classification of Serious game for Health (Non-Patient)

2.3 Classification by stage of disease

Following Merrill [35], we can classify the progression of an illness in the following stages (table 3):

Stage of disease	Serious game purpose
Stage of Susceptibility	Monitor
Presymtomatic Stage	Detect
Stage of clinical disease	Treatment, Therapy
Stage of disability	Rehabilitation, Track and Trace

Table 3 Stage of Disease

- **Stage of Susceptibility**
  This is the first stage, in which the person is still healthy. Nevertheless, some people have a genetic predisposition to develop certain illnesses later in life, so even in this healthy stage it is advisable to perform periodic checkups. A serious game in this stage helps the user to familiarize with monitoring procedures, and with illnesses that he or she will possibly develop later in life. Environmental risks or unhealthy surroundings can also affect the probability of developing illnesses, so this should also be taken into account.
- **Presymptomatic Stage**
  In this stage, people still feel healthy although the illness is already present. For example, the number of viric particles may still be too small to produce a response in the body, or a failing organ may still be able to cope with the added pressure of the illness with no external indications. The beginning of this stage may be discovered by the periodic checkups mentioned above. In this stage, the specific illness is now known, and the chances of developing it are very high, so more focused serious games can be used to show the patient the relevant aspects of his illness and his treatment.
- **Stage of clinical disease**
  In this third stage, the symptoms of the illness are already manifest in the patient. If the illness was not detected in the previous stages, serious games can be used to familiarize the patients with the expected progression of their illness, and the treatment procedures. Alternative treatments can also be shown using games. Games intended to be played by doctors or other medical staff usually focus on this stage as well.
- **Stage of recovery, disability or death**
  In this last stage of the illness, three different outcomes are possible: the illness may be cured, returning the patient to health or to another stage of susceptibility, or it may have serious effects on the patient's health, making them unable to function at previous levels (disability). The worst outcome of an illness, of course, is the death of the patient. Serious games in this stage normally deal with the rehabilitation procedure, or helping the patient cope with their disabilities.

2.4 Classification by functionality

Rego et al. [41] identify some criteria for the classification of serious games for health. We build upon their criteria and add some more interesting characteristics. The description of our classification system follows:

- **Application area**
  The application area or domain describes the part of the real world being modelled by the software. In serious games for health, we will distinguish two main aspects: cognitive skills such as memory, attention span, concentration and reasoning (Cog) and motor skills such as general coordination or re-learning to walk after injuries (Mot).
- **Interaction Technology**
  Interaction technogies are the different paradigms for establishing communication between humans and computers. Both hardware and software interfaces are included. Traditionally, mouse and keyboards have been used; newer means of interaction include Virtual Reality (using head-mounted displays (HMDs), computer monitors, haptic or pseudo-haptic devices such as gloves or pens, or tracking devices. Webcams and web applications are also common. Patients can affect virtual objects in real-time using a variety of senses (vision, hearing and touching).
- **Game Interface**
  The virtual world inside the game can simulate the real world (three dimensional games, 3D) or provide a top-bottom or sideways perspective of a simpler world (two timensional games, 2D)
- **Number of Players**
  The number of users concurrently using the world of the game. In general, we distinguish simple player games (for one person) and multiplayer games (for two or more people).
- **Game Genre**
  Games can be categorized according to their gameplay; we can distinguish adventure, strategy, simulation, sports and puzzles, among others. In games for health, the games which evaluate coordination and movement are common in rehabilitation; other genres are also used for different tasks.
- **Adaptability (Yes/No)**
  Old games used to have a fixed level of difficulty, which could either be programmed or chosen before the game started. Nowadays, many games try to adapt their difficulty to the skill of the player, in order to increase playability and enjoyment by the user. In e-health, adaptability is an excellent trait because it allows the patient to test and superate his limits in a controlled manner.
- **Performance Feedback (Yes/No)**
  Performance feedbacks are the indications of the game dealing with showing the users their status and abilities. They allow patients to feel confident they are progressing and to detect and fix their failures. The feedback can be auditive, visual or haptic.

- **Progress monitoring**
  For patient evaluation, having logs of the patients actions inside the game can be
  an invaluable asset. We call this feature progress monitoring, since it allows the
  doctors to monitor the progress of the patients as a function of time.
- **Game portability**
  Portability refers to being able to physically move the game hardware. In partic-
  ular, we distiguish games located at a hospital or clinic, and games which can be
  used at home or which can be held portably by the user.
- **Game Engine**
  A game engine is a platform which provides commonly used functionality in
  games, so that game developers can focus on higher level game design and func-
  tionality. The engine provides an API to access lower level functionality and a
  set of predefined models and materials and scenes [14]
- **Platform**
  The hardware the game is run on. This may include personal computers (PCs),
  commercial game consoles (Nintendo Wii, Microsoft Xbox), portable consoles
  or custom hardware.
- **Health Objective**
  Objectives related to health include monitoring, detection and treatment of ill-
  nesses, rehabilitation, education, health and wellness, training for patient and
  training for non patient so that they can take care of themselves, or at least know
  and understand the caring procedures carried upon them. Other general objec-
  tives include healthy habits such as exercise, sleeping patterns and making pa-
  tients avoid excessive alcohol intake and smoking.
- **Connectivity**
  Games might require an internet or network connection (online) or they may be
  played in standalone computers (offline).

3 Review studies

Several Serious games and applications for health have been reported in literature. In
this section we review the work developed in this area, including additional games
from commercial or online sources. We provide a short summary of each game, indi-
cating their most relevant characteristic, and finish the section with a table overview-
ing the characteristics of all the games according to the different aspects detailed in
the previous section. The games studied are:

- **CHF telemanagement systems.** [18]:
  Home Automated Telemanagement (HAT) system for chronic disease manage-
  ment in the patients home. The system helps patients with congestive heart fail-
  ure (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. An internet connection is required.

- **Healthcare monitoring in the home** [17] :
  A medical diagnostic gaming environment that is used to gather patient information in a casual, non-obtrusive manner that is relaxing for the patient.
- **The u-health monitoring system with a Nintendo DS** [31] :
  This application displays the bio-signals of patient onto a monitor of personal computer and LCD of a Nintendo DS using a bio-signal measurement device connected via wireless protocol.
- **Unobtrusive Health** [34]:
  21 Tally is a collection of 2D games used to detecting divided attention unobtrusively, by using performance on a computer game designed to force players to attend to different dimensions simultaneously in order to succeed.
- **EEG-Based Serious Games** [58]:
  The EEG-based concentration games named Brain Chi(2D) and Dancing Robot(3D) were developed for concentration level control.
- **Match-3** [46] :
  A serious game designed to combat childhood obesity. The Wii-mote is being used for a rowing action which propelled the coracle forward, while direction is altered by leaning left and right on the Wii-fit.
- **Medical Gaming Environment for Diagnosis and Management of Parkinson s Disease** [6] :
  A medical diagnostic gaming environment that is used to gather patient information in a casual, non-obtrusive manner that is relaxing for the patient. The system employs the novint falcon human interface device [25] to guide a patient who may have problems reaching a specified goal within the game.
- **Bartolome et.al.** [8]:
  This 3D game can analyze the behavior and promote certain social skills (conversation, negotiation etc.) of people with Neurological development Disabilities. The treatment has been planned at three levels. Each level treats a characteristic related to socialization, integration and the expression of feelings.
- **Neuropsychological Rehabilitation** [21] : single-user and first-person-shooter tasks. Patients navigate through the virtual environment and perform cognitive tasks.
- **Chronic Pain Rehabilitation** [47]:
  This system provides multimodal interaction including full body motion capture by the use of Microsoft Kinect, and other biosignal capture devices. The patients can manage their state and train physically on their own.
- **Serious Games for Upper Limb Rehabilitation Following Stroke** [10] : Several systems, developed by research group at the University of Ulster, for upper limb stroke rehabilitation through the integration of 3D virtual environments and sensor and camera technology. There are 5 games including; Game 1) Catch task for bilateral rehabilitation. Game 2) Adaptive whack a mouse game which designed to encourage movement and to improve the accuracy and speed of the users upper limb movement. Game 3) Rabbit Chase developed for single arm rehabilitation (either right or left arm). Game 4) Arrow Attack for bimanual re-

habilitation (both arms) and Game 5) Virtual vibraphone, the use of Nintendo Wii remote controllers for wrist and arm rehabilitation.

- **Games for people with Parkinson's Disease** [52]:
These nine therapeutic games by Red Hill Studios and the School of Nursing at the University of California San Francisco can help Parkinson's disease patients increase their balance. The games are played by performing movements which are known to be beneficial for balance control and the movements are captured and processed by the system. Patients can use this immersive and engaging virtual world to practice gait and balance in a more interesting setting.

- **Re-Mission** [53]:
A video game with 20 levels that takes the player on a journey through the body of young patients with different kinds of cancer, released by the nonprofit HopeLab. The main aim is to engage young cancer patients through entertaining game play while impacting specific psychological and behavioral outcomes associated with successful cancer treatment.

- **A Sensory Gate-Ball Game** [28] :
PC-based 3D graphics game design for aged people, uses a realistic gate-ball stick and balls as interfaces. In the game, players use the same stick and ball as the real gate-ball.

- **Dancing in the Streets (DITS)** [15]:
DITS is a mobile phone version of the popular arcade game Dance, Dance, RevolutionTM(DDR). Instead of using a dance pad, DITS uses wireless 3-axis accelerometers that are worn around the players ankles and uses a mobile phone to control the game and to display graphics.

- **Fitness Adventure** [30]:
This application platform, which is able to take advantage of a variety of mobile phones, location information and Bluetooth GPS receivers, combines mobile games with exercising outdoors. The end result is a location-aware fitness game.

- **Virku - Virtual Fitness Centre** [56]:
This system allows users to exercise in a virtual environment. The game is controlled by a user interface based on an exercise cycle, and users may practice individually or in a group. The virtual world affects the difficulty of the exercises in a coherent manner, for example changing the resistance of bycicle pedals during virtual hill climbing.

- **MoFun Circus** [13]:
This instalation, located at Heureka (Vantaa, Finland) is a cooperative multiplayer action game. After users meet in a circle, a trampoline is created, and users move and capture falling objects. A camera is used to follow the users and display the activity on-screen.

- **HumanSim (Preview)** [5]:
This preview shows the appearence of the HumanSim immersive world. In this world, doctors and nurses train to learn the nuances of complex, unusual or other error-prone tasks until they become experts. A high-quality virtual hospital is modelled, including operating rooms and other important spaces, and populated with doctors and nurses. It runs on an Apple iPad.

- **Virtual Dental Implant Training Simulation Program** [9] [16]:
  This software provides a 3D virtual environment for students to train in the correct decision-making protocol to determine patient preparation (both physical and mental) for dental implant surgery. After ensuring that surgery is needed, the student can practice the procedure in a safe and realistic environment.
- **Nursing and Midwifery** [50]:
  This program helps nurses and midwives increase their ability to assess patients. The interactive scenario is based on the simulation of the 36 weeks of pregnancy realistically. Multimedia and virtual reality are combined so that the user can move inside the hospital, interact with patients and perform the needed tests with the correct instruments.
- **Pulse!! The Virtual Clinical Learning Lab** [9] [3]:
  This is the first immersive virtual learning space where health care professionals can train their clinical skills. State-of-the-art graphics create a virtual world in which both civilians and military professionals in the field of health care can practice clinical skills in an interactive and believable universe. This allows them to respond better to patients with injuries due to combat, bioterrorism or other catastrophes.
- **EMSAVE ("Emergency Medical Services for the disAbled" Virtual Environment)** [55] [22]:
  is a system for training in emergency medical procedures concerning disabled patients. It allows users to experience emergency situations involving disabled persons.
- **MUVE Market Virtual Patient Care Simulation Lab** [37]:
  This software can be used to create simulations of patents useful in training students and professionals (nurses, pharamacists, paramedics, emergency medical technicians, social workers, ...). The environment is part of the Second Life MMORPG mentioned previously.
- **Olive: 3D Hospital Training** [48] [44]:
  The On-Line Interactive Virtual Environment (OLIVE) is a dynamic software platform which eases the development and deployment of collaborative virtual worlds. The worlds can be customized and privacity and security are taken into account in the platform. In the virtual world, users can perform planning, training, rehearsing and operating over long distances using computer networks. The technology has been used to train different scenarios in a hospital operating theatre. Real nurses, doctors and patients appear in the game using their avatars, and remote users can receive standarized Sharable Content Object Reference Model (SCORM) training data and participate in the virtual world.
- **Game-based learning for Virtual Patients - Multi patients** [45]:
  Second Life is a massively multiplayer online role playing game (MMORPG) which allows users to choose a different lifestyle. A region in Second Life created by the Faculty of Medicine at Imperial College London provides a learning space where virtual patients suffering five different respiratory illnesses (such as lung cancer or pneumonia) can be diagnosed, investigated and treated by play-

ers wanting to perform role-playing learning activities under the feedback and guidance of medical staff.

- **Nurse education** [4] :
  A virtual learning environment (Second Life), for use in nurse education. Developed at Glasgow Caledonian University.
- **Virtual Patient** [2]:
  This system, developed by Keele University, trains pharmacists by using a virtual patient. Traits such as race, age and gender (which sometimes affect responses to procedures and medications) are taken into account in the treatment of patients, so that learners can understand their clinical significance. Dyspepsia and hypertension are examples of the possible illnesses included in the system.
- **Medical Simulation Training Program(JDoc)** [51]:
  This systems provides a computer-aided junior doctor simulator, using both 1st and 3rd person perspectives to produce immersion. It can be used for training and teaching junior doctors their interpersonal, communication and decision making skills, and to ease the transference of the medical information available to them.
- **VI-MED** [36] :
  A virtual training to be used as a precursor and as a supplement to real practical training.
- **Sabri2010** [43]:
  An interactive, multi-player serious game for the purpose of training cardiac surgeons/residents the series of steps comprising the Off-Pump Coronary Artery Bypass (OPCAB) surgical procedure.
- **Air Medic Sky 1** [54]:
  This interactive bio-feedback game consists of mini-games and lectures which describe the basic concepts required for efficient communication and teamwork resulting in pacient safety. Complex situations are presented which mirror common occurrences in the work of junior doctors. The solving of these solutions allows doctors to gain insights in how physiological functions affect performance.
- **Terveellinen Ateria** [26]:
  This interactive program aids practical nurses and comprehensive school staff train in the practical aspects of preparing meals for people with different nutritional requirements. The Finnish plate model is used as a basis, and it can be applied to solve the dietary needs of people. The energy content of meals is calculated according to the foods included and their size. Teaching healthy nutrition and weight management habits to the general population is one objective of the program.
- **MC Urho** [12]:
  This system contains a plethora of information regarding lifestyle effects on health. The game can be used in biology and health education classes to teach young people about the effects of smoking, high blood pressure and cholesterol.
- **Valion Energiasummaaja** [11]:
  This online game, aimed at both children and adults, helps build a healthy and balanced breakfast (or general snacks). Food is chosen from a variety of options

in a virtual refrigerator, and dragged into a plate. The effects of the meal on blood sugar are shown, and possible improvements in the meal are suggested.

- **Fatworld** [49]:
  This videogame explores the relationships between nutrition, obesity and socioe-conomic factors in the contemporary U.S. Budgets, subsidies, regulations and physical world characteristics are taken into account.
- **The Food Detectives Fight BAC! game** [19]:
  A 2D web base game for 8-12 year old kids to learn about foodborne illness. Created by The Partnership for Food Safety Education.

4 Discussion

Tables 4 and 5 display the classification and comparison of health games. The dash means that this feature is not mentioned in the bibliographic reference which described the game. Figures 4 and 5 provide a graphical summary of the data.

The objectives are quite varied, but an emphasys can be seen on professional users and rehabilitation. We can see that both motor and cognitive abilities are well represented application areas. Progress monitoring, performance feed and portabilities are important features, present in the majority of the games. We can see that adaptability is a useful characteristic, present in about 3/4 of the games.

There are a few used platforms, but most of the games have been designed to run on PCs, and internet connection is used in almost half of the games surveyed. Interaction technologies are quite varied, although the standard mouse interface is used in almost half of the games. There is a wide variety of engines used, although this is not an often reported characteristic. Flash is the engine used most often, by a wide margin, and most of the games are currently single player. The simulation and action genres dominate, although there is a large variety of other genres, and 2D and 3D interfaces are both well represented in the sampled games.

5 Conclusion

We have studied forty serious games from different areas of health and well being, classifying them according to their characteristics, and described the most commonly present ones. The typical game can be summarized as a portable PC game programmed in Flash, using mouse interaction and including progress monitoring, performance feed and adaptability, although the variability of games is quite large in many aspects. For the future improvement, authors plan to explore more the serious games and applications for mobile devices such as iPhone, iPad, etc.

	[18]	[17]	[31]	[34]	[58]	[46]	[6]
App. area	Mot	Mot	Mot	Cog	Cog	Mot	Cog
Interac tech	Wiimote	WSN	Electrode	Mouse	EEG	Wii Fit	Novint
Interface	2D	2D	2D	2D	2D	3D	2D
Players	Single	Single	Single	Single	Single	Single	Single
Genre	App	App	App	Puzzle	Action	Advanture	Action
Adaptability	No	No	No	Yes	–	Yes	Yes
Progress Monit	Yes	Yes	Yes	Yes	–	–	–
Perf. Feedback	Yes	Yes	Yes	No	–	Yes	–
Portability	Yes	No	Yes	Yes	No	Yes	Yes
Engine	Flash	–	PALIB	–	–	–	SDK
Platform	Wii	PC	DS	PC	PC	Wii	PC
Objective	MON	MON	MON	DET	DET	TRT	TRT
Connectivity	On	On	On	Off	Off	Off	Off

	[8]	[21]	[47]	[10]/Game1	[10]/Game2	[10]/Game3	[10]/Game4
App. area	Cog	Cog	Mot	Mot	Mot	Mot	Mot
Interac tech	Wiimote	Mouse	Kinect	VR	HMD	Webcam	Webcam
Interface	3D	3D	3D	3D	3D	2D	2D
Players	Single	Single	Single	Single	Single	Single	Single
Genre	Role Play	Role Play	Advanture	Action	Action	Action	Action
Adaptability	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Progress Monit	Yes	–	Yes	Yes	Yes	Yes	Yes
Perf. Feedback	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Portability	Yes	Yes	No	Yes	Yes	Yes	Yes
Engine	Director	–	Unity3D	OGRE	–	XNA	XNA
Platform	PC	PC	PC	PC	PC	PC	PC
Objective	TRT	REH	REH	REH	REH	REH	REH
Connectivity	Off	Off	Off	Off	Off	Off	Off

	[10]/Game5	[52]	[23]	[28]	[15]	[30]	[56]
App. area	Mot	Mot	Cog	Mot	Mot	Mot	Mot
Interac tech	Wiimote	–	Mouse	Sensor	Sensor	RFID	Cycle
Interface	2D	2D/3D	3D	3D	2D	2D	3D
Players	Multi	–	Single	Single	Single	Single	Single
Genre	Action	Mix	Adventure	Sport	Exergame	Exergame	Exergame
Adaptability	Yes	–	Yes	Yes	No	Yes	Yes
Progress Monit	Yes	–	Yes	Yes	Yes	Yes	Yes
Perf. Feedback	Yes	–	Yes	Yes	No	Yes	–
Portability	Yes	–	Yes	No	Yes	Yes	No
Engine	–	–	–	–	–	SMAC	–
Platform	PC	PC	PC	PC	Mobile	Mobile	PC
Objective	REH	REH	EDU	H&W	H&W	H&W	H&W
Connectivity	Off	–	Off	Off	Off	On	Off

	[13]	[3]	[55]	[5]	[9]	[50]	[48]
App. area	Mot	Cog	Cog	Cog	Cog	Cog	Cog
Interac tech	Camera	Mouse	Mouse	Touch	Mouse	Mouse	Mouse
interface	2D	3D	3D	3D	3D	3D	3D
Players	Multi	Single	Single	Single	Single	Single	Multi
Genre	Action	Simulation	Simulation	Simulation	Simulation	Simulation	Simulation
Adaptability	–	Yes	Yes	Yes	Yes	Yes	Yes
Progress Monit	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Perf. Feedback	–	Yes	Yes	Yes	Yes	Yes	Yes
Portability	No	Yes	Yes	Yes	Yes	Yes	Yes
Engine	–	–	NeoAxis	Unreal	BreakAway	–	–
Platform	PC	PC	PC	Ipad	PC	PC	PC
Objective	H&W	P	P	P	P	P	P
Connectivity	Off	On	Off	Off	Off	Off	On

Table 4 Classification and comparison of health games(1)

	[45]	[4]	[2]	[51]	[36]	[43]
App. area	Cog	Cog	Cog	Cog	Cog	Cog
Interac tech	Mouse	Mouse	VoiceRe.	Mouse	Mouse	Mouse
Interface	3D	3D	3D	3D	3D	3D
Players	Single	Single	Single	Single	Single	Multi
Genre	Simulation	Simulation	Simulation	Simulation	Simulation	Simulation
Adaptability	Yes	–	Yes	Yes	Yes	Yes
Progress Monit	Yes	–	Yes	Yes	Yes	Yes
Perf. Feedback	Yes	–	Yes	Yes	Yes	Yes
Portability	Yes	Yes	Yes	Yes	Yes	Yes
Engine	Second Life	Second Life	–	Torque	–	In House
Platform	PC	PC	PC	PC	PC	PC
Objective	P	P	P	P	P	P
Connectivity	On	On	On	On	On	On
	[54]	[26]	[12]	[11]	[49]	[19]
App. area	Cog	Cog	Cog	Cog	Cog	Cog
Interac tech	Biofeedback	Mouse	Mouse	Mouse	Mouse	Mouse
Interface	3D	2D	2D	2D	2D	2D
Players	Multi	Single	Single	Single	Single	Single
Genre	Simulation	Puzzle	Quiz	Puzzle	Role Play	Puzzle
Adaptability	Yes	Yes	Yes	Yes	Yes	Yes
Progress Monit	Yes	Yes	No	Yes	Yes	Yes
Perf. Feedback	Yes	–	–	–	Yes	No
Portability	Yes	Yes	Yes	Yes	Yes	Yes
Engine	–	Flash	Flash	Flash	Flash	Flash
Platform	PC	PC	PC	PC	PC	PC
Objective	P	NP	NP	NP	NP	NP
Connectivity	On	On	On	On	Off	On

Table 5 Classification and comparison of health games(2)

Fig. 4 Breakdown of the values of each characteristic of serious games for health present in our survey(1)
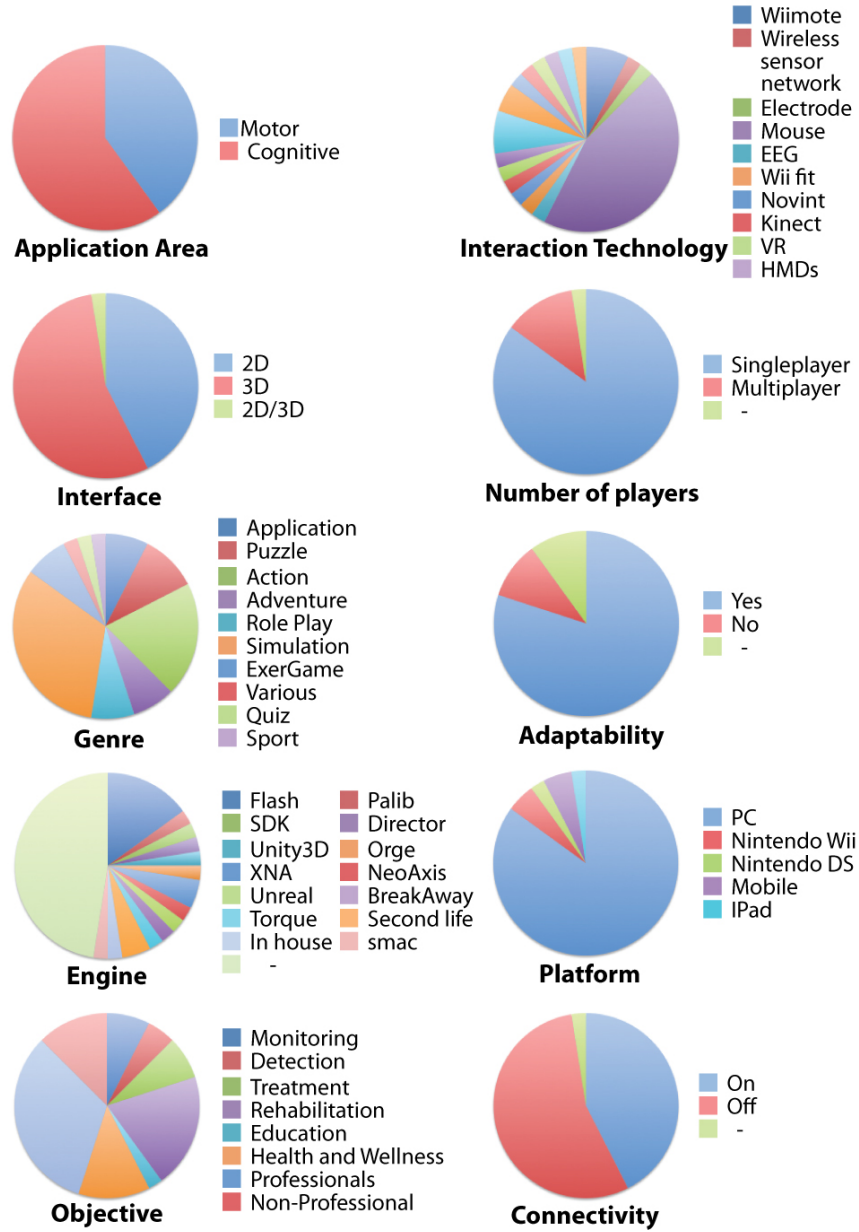
Fig. 5 Breakdown of the values of each characteristic of serious games for health present in our survey(2)

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