Chapter 6

Games for Health

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6.1 INTRODUCTION

Computer games use technology and favour learning, discovery and creativity [1]. The potential of computer games in relevant tasks has been widely demonstrated [2]. Indeed, serious computer games rely on entertainment to allow advancing training, education, health, public policies, strategy, mental calculation and decision-making, among others [1, 3]. In health, either computer games or computer games’ technologies have been
used for several years to support health-related tasks [4]. One example is LapSim (Figure 6.1):

In 1995 in Gothenburg, Sweden, Dr. Anders Hyltander, a senior GI surgeon at Sahlgrenska University Hospital, believed that novice surgeons could be trained in critical skills and procedures long before entering the operating room. He theorised that real-time simulators could be developed to bridge the gap between classroom pedagogy and patient. Together with three young and skilled software engineers, Dr. Hyltander tested that hypothesis to great success. [5]

Nowadays, computer games and computer games technology’s applications are broad. Figure 6.2 [6] shows the most common applications:

- **Health personnel training** [7]: This is related to surgery training for surgical planning, new surgeons’ training, nurses training, etc. (Figure 6.2).

- **Patient training** [8]: This is related to making patients understand medical procedures or to build up healthy habits.

- **Therapy** [9]: This is related to motivating patients with temporary or chronic pathologies or diagnostics to re-gain or gain some skills.

- **Health policies understanding** [10]: This is related to strategies or experiments to promote health policies among the population.

FIGURE 6.1 Basic medical task training adapted from LapSim [6]. This minigame requires the trainee to insert rings in the sticks using medical tools. The game is aimed at acquiring the dexterity skills required for laparoscopic surgery.
Computer games technologies used in health are also diverse and include, among others:

- **Sensors** [11, 12]: Sensors are used to gather and measure patient or trainee data.

- **Virtual reality** [13]: VR is used to simulate health environments as realistically as possible.

- **Mobile devices** [14]: Mobile devices are used to interconnect and favour mobility in health games and health systems in general.

However, the use of game technologies does not necessarily mean that the health application will be a game, as discussed later. Despite this, games seem to be a tool to enhance learning, practice and make it more enjoyable. Minigames seem to be a good way to implement games for health as they allow focusing on concrete tasks [15, 16] (Figure 6.1). We present an overview of how games can be used to favour health. Section 6.2 discusses previous works related to games for health and explain examples of each of the categories shown in Figure 6.2. Section 6.3 describes principles and
methods for developing games for health. Section 6.4 discuss games for health applications beyond human beings. Section 6.5 explains the use of game technology for health in non-game environments. Section 6.6 presents a discussion and Section 6.7 is the conclusion.

6.2 PREVIOUS WORK

We present and discuss a representative example of games for health. The most common application of games for health are [17] referred to in Figure 6.2 and include health personnel training, patient training, therapy and health policies understanding. Next, we briefly explain some examples for each of these categories.

6.2.1 Health Personnel Training

Diverse surgical scenarios can be reproduced using virtual reality. They offer the advantage of repeatability of the training sessions and objective measurement of the developed skills without risk for the patient. These allow for the evaluation and study of mistakes. De Paolis [18] presents a serious game for training on suturing in laparoscopic surgery. He proposes a set of parameters to assess the level of skills developed by the trainees and focuses on the physical modelling of the virtual environment. Assessment is done by means of a thread and the two clamps controlled by two haptic interfaces. The goal of the system is to develop in the trainee important skills required in laparoscopy surgery, such as:

- Good eye-hand coordination
- The ability to manipulate the surgical instruments
- Techniques for performing the suture node

The game was developed under the following requirements:

- The behaviour and appearance of the human tissue and suture thread should be as realistic as possible within the simulation.
- The number of fiducial points on the tissue, test duration time, number of elements of the thread and the size of the tissue must be configurable.
- The trainee must receive feedback through a haptic device that simulates the force of the virtual surgical forceps.
The skill of the trainee during the execution of the task must be measured.

Numerical indicators to measure the trainees’ skill include:

- Time elapsed between the completion of the node and the first contact of the needle with the tissue (duration).
- Maximum distance between the real point of entry of the needle into the tissue and the ideal point indicated by a marker (accuracy).
- Maximum force used during the simulation in order to pierce the tissue by means of the needle (force peak).
- The sum of the forces applied to the tissue over the threshold of breakage of the tissue (tissue damage).
- Difference between the tangent and the normal to the surface at the point of the needle entry (angle of entry)
- Total distance travelled from the needle in order to complete the task (distance).

The overall score is the average of all previous specified parameters, except from distance. Figure 6.3 schematises the system (for more details see Figure 4, p. 484 in De Paolis [18]).

FIGURE 6.3 Serious suture game using two haptic devices. The incision and thread are shown in the interface.
Ribeiro et al. [19] describe a game to train the general public personnel in basic life support (BLS). BLS is used before patients can be given full medical care in victims of life-threatening illnesses or injuries and usually occurs in pre-hospital settings. This game was developed in collaboration with health care professionals, to train and evaluate the public in BLS (Figure 6.4). Within the game, the player chooses either to play in training mode or in evaluation mode. In training mode, the player can train the different game cases. If the player chooses the wrong procedure, a warning appears. In disastrous or emergency events, a layperson may become the first health personnel at hand, thus, some knowledge is of benefit. The training could be extended to medical personnel specialised in disaster response and nurses.

Another example of this kind of game is described in the previous section (Figure 6.2). Overall, the idea of this sort of game is to simulate real environments where medical procedures or protocols may develop as realistically as possible. These may require accurate models, tasks and triages.

6.2.2 Patient Training

Users participate and engage in an activity if they are motivated. Motivation can be achieved through video games as they offer fun experiences. Ijaz et al. [20] propose an exergame platform used to investigate motivation and physical activity and to favour activities related to wellbeing. They study player’s experiences related to:

- Enjoyment
- Player’s motivation
- Perceived experiences
- Physiological and vitality variables

In *Pokémon Ride*, the player explores Sydney in a DeskCycle and throws Poké balls to appearing Pokémons. The game displays information related to real-time performance and physiological information. In *Balloon Shooter*, the player rides on a DeskCycle near Sydney Hyde Park and shoots balloons. The game displays information on heart rate, time spent and calories. Figure 6.5 shows the idea. For images of *Pokémon Ride* and *Balloon Shooter* refer to Ijaz et al. [20, Figures 2 and 3, p. 3].

Herrera, Navarro and Marín [21] explain how a simulated cavity navigation environment can be used to support pre- and post-procedural
FIGURE 6.4 State machine in a VR game for BLS training. (Adapted from Ribeiro, C., Tiago, J., Monteiro, M. & Pereira, J. (2014). SeGTE: A Serious Game to Train and Evaluate Basic Life Support. 2014 International Conference on Computer Graphics Theory and Applications (GRAPP), Lisbon, Portugal, pp. 1–7. Images from the virtual environment can be seen in Ribeiro et al. [19], Figure 2.)
education of patients by interactively showing them the pathology and the medical procedure that is going to take place. The doctor must follow the marked path while explaining the procedure to the patient. Indeed, most patients stated that they would feel confident after an explanation with the simulation environment (Figure 6.6).

Overall, the idea of these sort of games is to motivate healthy practices among people and to make them understand medical procedures better.

FIGURE 6.5  Games favouring wellbeing in players. AR content is superimposed on the path to motivate exercise.

FIGURE 6.6  Interactive navigation system. Left: otolaryngology procedure. Right: inside a 3D reconstructed stomach. The dark grey spheres are mistakes in the paths. The medium grey spheres mark the suggested expert path. The light grey spheres are successful path coincidences by the user. Both systems were also used to explain the procedure to a group of patients.
6.2.3 Therapy

Therapy activities may not be easily accessible due to cost and demand. Additionally, therapy sessions may be laborious and non-motivating. Navarro-Newball et al. [22] propose a video game for therapy related to speech mechanisation in children with auditory deficiency using cochlear implants. The application workflow is as follows. It starts with an initial task list given to the patient’s parents by the therapist. The task list contains a file that is uploaded by the video game and must be practiced by the child using a microphone. Then, the result is stored and received by the therapist. The process must be repeated until the patient achieves correct pronunciation. To complement the therapy activities, the game proposes a series of minigames displaying various pronunciation challenges. Minigames are implemented as challenges. A challenge is completed once a minigame is successfully repeated at least eight out of ten times. One example challenge consists of filling buckets with food for feeding a bear. If the corresponding phoneme is pronounced correctly, the corresponding bucket will be filled with food (Figure 6.7).

Henriksen et al. [23] explain a game aimed at recovering patients with upper limb amputations affected by phantom limb pain (PLP). The system was implemented using motion capture sensors and haptic feedback.

It includes a bending game to grab, move, bend and release; a location discrimination game (Figure 6.8); and a frequency discrimination game where users are able to distinguish haptic frequencies. There is evidence that with these games, patients gain control of the amputated limbs.

Overall, the idea of these sort of games is to aid people with difficulties performing a physical or cognitive task gain some control and overcome their limitations. It is common that these sorts of games rely on technologies such as sensors, pattern recognition and haptics.

6.2.4 Health Policies

Public health policies should be efficiently communicated to assure democratic access to health and the quality of life of the population. Games can show rich combinations of text, audio, graphics and interaction, and may allow great flexibility for presenting health content. They can stimulate the user to act instead of passively receiving information. Indeed, gaming may be used to create many kinds of social connections. Games can be used to empower the players [17]. For example, Guana et al. [24] present a game

![Figure 6.8](image-url)
that can support education on reproductive health for governments and health organisations. UnderControl [24] is focused on teens and young adults and educates players about contraception and sexually transmitted illnesses (STIs). In this game, the player has to place a variety of contraceptives with diverse defensive capabilities that impede sperm to reach a female egg. Enemies are new STIs and the player can use different contraceptive methods depending on the level (Figure 6.9).

Overall, the idea in these types of games is to communicate health policies and education to society. The games can be focused on the portion of the population to whom the policy or campaign is oriented. It is common that these kinds of games use technologies such as highly interconnected WEB or mobile applications.

6.3 DESIGNING GAMES FOR HEALTH

In this section, we discuss some universal game design principles that can be applied for games for health design; then, we present a proposal for automatic games for health development.

6.3.1 Basic Principles from the Entertainment Industry

Both games for health and games for entertainment allow player’s engagement over long periods of time. Chances are that the longer a player plays a game for health, the better the player’s improvement. Ushaw et al. [25]

**FIGURE 6.9** A variety of contraceptive methods can be used to avoid sperm contact with the female egg. (Redrawn by Andrés Adolfo Navarro-Newball. For images of UnderControl refer to Guana et al. [24], Figure 1.)
state that player engagement techniques from the entertainment industry can be transferred over to games for health. To achieve that, they propose design practices that ‘bring a heightened sense of engagement and replay value to games for patients that do not distract from the main health benefit’ such as [25]:

- **Platform and Input Device:** hardware platform and input device should be chosen according to the medical intentions of the game. Choices depend on the research needs and the target group of users. For example, while most people are familiar with touchscreen interaction due to the proliferation of smartphones and tablets, a traditional joypad may seem better to those unfamiliar with modern console gaming. Available systems need to be compared as each one has strengths suited to specific needs of gaming health projects.

- **Player Feedback and Player Ability:** feedback is required for retaining user’s attention. It should not be punitive but encouraging, rewarding and positive. The reward should outweigh the penalty as the idea is to encourage ongoing participation with the game by providing longer term goals and feedback to the player. This can be done implementing an achievement scheme [9 as cited in 16].

- **Comfort Rewards:** implementing a comfort rewards scheme as a microlevel mechanism to provide constant positive encouragement as the game progresses. Successful completion of a task should be measured using a broad range of parameters. This means that if the player is making a reasonable effort, the game decides that the task was achieved. The player will more likely continue the more rewarding the experience is. If the latter happens, continued engagement is promoted.

- **Level Structure:** the content of each level should become more challenging as the player makes progress. Levels limit the ways players interact allowing consistent focus on the specific behaviour of interest.

- **Focused Player Action:** to encourage the player to focus on one particular action at any time is of great benefit (Figure 6.2). Focus on specific player actions is enabled from clear player feedback, comfort rewards and a level-based structure. The parameters of success can be more tolerant, making positive feedback more likely if the
game is focused on assessing whether one task has been achieved. Additionally, focusing on one task favours clarity on the medical study that the game for health is enabling.

- **In-Game Help**: the option to ask for help should be available at any point and not just after failing to accomplish a task. Instructions should be available on screen and simply presented.

- **Inclusive of Family**: players enjoy involving other family members in the game. This increases dosage time as games are played communally with some element of competition.

- **Simplicity of Game Design**: accessibility increases when innovation or complication in the game design are avoided. Tasks such as matching an icon to a target, gauging the length of time to hold down a button and guiding an avatar through a series of gates can be integrated into gameplay because they are easily understood. Simple and well-known game genres may be applicable.

Although the previous principles are for games aimed at patients, these concepts could be extended to medical personnel in training. However, some parameters should allow for less tolerance as it is expected that medical personnel are less prone to mistakes than patients.

### 6.3.2 Towards the Automation of Games for Health Development

Best practices can be applied during the design and implementation processes. For example, Matínez et al. [26] propose a computational tool for constructing personalised minigames aimed to support language therapy in children with hearing loss. They apply the Software Product Line Engineering (SPLE) paradigm. SPLE enables the efficient management of a set of products that have common and variable elements and belong to a domain. This way, it is possible to share reusable aspects, satisfy specific needs of a market and software can be developed in a prescribed manner. This kind of paradigm enables users to configure new products. Figure 6.10 exemplifies this idea [27]. Here, the tool has three main modules. In the therapist’s module, the therapist personalises and assigns the activities to be carried out by the child. In the child’s portal, the child performs the activities assigned by the therapist. The minigames generator creates the game in real time. It is important to consider that 'the selection of a video game engine to develop core assets of a Software Product Line (SPL) of
minigames could be highly influenced by the requisites of the SPL, differentiating it from the usual selection criteria applied when building complex video games’ [28, p. 1].

Thus, software engineering methods and commercial principles can be extended for use in the development of serious games for health.

6.4 BEYOND HUMAN HEALTH

Xu et al. [29] describe a system to train in dog anatomy supported by virtual reality. The system was implemented using a game engine and the virtual reality toolkit (VTK). It is focused on veterinary assessment for veterinary students studying anatomy (Figure 6.11). Thus, game technologies and video games can be extended to animal health. As the authors state: ‘If the efficiency of veterinarian medicine can be improved, then more dogs can receive better medical care, letting them live longer, happier lives’. This statement can be extended to other animals in a world requiring the protection of biodiversity.

6.5 OTHER USES OF GAME TECHNOLOGIES IN HEALTH

Technologies such as augmented reality (AR) and virtual reality (VR) are common in serious games [30]. However, their proper use does not imply the creation of a video game. For example, Matu et al. [30] explain a system where a trainer uses two virtual robotic arms, which are superimposed on
a video feed to the trainee using AR. The system allows the demonstration of diverse tasks performed by the trainer to guide the trainee. The trainee can follow and perform the task within a 3D image displayed through a stereoscopic display (Figure 6.12).

Rapetti et al. [31] describe a VR navigation system for prostate biopsy. In this system, the position of the needle and the patient anatomy are tracked by a system which provides orientation and position with respect to the surgical bed. In the operative room, the surgeon is presented with a stereoscopic volumetric rendering of the patient’s anatomy and a virtual

![VR animal anatomy system for veterinaries. A 3D image of the skull is superposed over a 3D virtual curved screen where information is displayed. (Redrawn by Andrés Adolfo Navarro-Newball. For the original image refer to Xu et al. [29], Figure 6.)](image)

FIGURE 6.11  VR animal anatomy system for veterinaries. A 3D image of the skull is superposed over a 3D virtual curved screen where information is displayed. (Redrawn by Andrés Adolfo Navarro-Newball. For the original image refer to Xu et al. [29], Figure 6.)

![The trainer guides the trainee using virtual tools. (Redrawn by Andrés Adolfo Navarro-Newball. For the original image refer to Matu et al. [30], Figure 5.)](image)

FIGURE 6.12  The trainer guides the trainee using virtual tools. (Redrawn by Andrés Adolfo Navarro-Newball. For the original image refer to Matu et al. [30], Figure 5.)
The idea is to use a virtual reality navigation system where targeted biopsy is performed under the guidance of virtual images (Figure 6.13).

Overall, game technology does not always need to be used to implement a game. Useful health systems can be implemented relying on these technologies. The challenges of creating a game which includes narratives, mechanics, arts and devices are not always required.

6.6 DISCUSSION

Games for health can be useful because they are enjoyable and motivate repeatability. They are usually implemented with available game technology. Additionally, game technology can be used to implement a health system that do not necessarily implement a game and can go beyond human health (e.g. animal health).

The development of games for health is a complex task that should follow most of the games for entertainment principles. However, it is common to focus on simple, measurable tasks that can be implemented on minigames. This way, finding ways to measure performance is easier. Still, automation of games for health generation is a desirable feature. However, in most cases, games are developed to solve specific situations.
approach could be helpful to make development more efficient. However, the context of the game should be very well understood, and the game engine chosen according to the game’s specific needs.

6.7 CONCLUSION

We have briefly presented computer games and their use. We offered a broad classification of games for health systems; these include games for training medical personnel, games for training patients, games for therapy and games for public health policies. However, games for health should not be limited to this categorisation as they may have more diversity. Applications range from mental health, surgery, reproductive health, disaster recovery to veterinary medicine.

REFERENCES


