BRNO UNIVERSITY OF TECHNOLOGY

FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

DEPARTMENT OF FOREIGN LANGUAGES

THE ROLE OF VIDEO GAMES IN HEALTH CARE AND MEDICAL TRAINING

BACHELOR'S THESIS

AUTHOR
AUTOR PRÁCE
Markéta Gálíková

SUPERVISOR
VEDOUCÍ PRÁCE
Mgr. Magdalena Šedrlová

BRNO 2019

Bakalářská práce

bakalářský studijní obor **Angličtina v elektrotechnice a informatice**
Ústav jazyků

Studentka: Markéta Gálíková   *ID:* 195230
Ročník: 3   *Akademický rok:* 2018/19

NÁZEV TÉMATU:

Využití počítačových her v medicíně

POKYNY PRO VYPRACOVÁNÍ:

Cílem práce je podat přehled o současném využití počítačových her v medicíně se zaměřením jak na lékaře (training), tak pacienta (healthcare). Získané poznatky budou kriticky analyzovány a zhodnoceny.

DOPORUČENÁ LITERATURA:

Arnab, Sylvester, I. Dunwell, K. Debattista. "Serious Games for Healthcare: Applications and Implications"

Bauman, Eric B. "Game-Based Teaching and Simulation in Nursing and Health Care"

Termín zadání: 4.2.2019   *Termín odevzdání:* 28.5.2019

Vedoucí práce: Mgr. Magdalena Šedrlová
Konzultant:

doc. PhDr. Milena Krhutová, Ph.D.
předseda oborové rady

ABSTRACT

This bachelor thesis deals with possible use of videogames and gaming-related technology in medical training and healthcare. General public often consider games as a waste of time or as a purely entertaining. Therefore, the aim of this thesis is to provide evidence of their usefulness and positive impacts on the field of medical training and healthcare. First part of this work refers to and critically analyses the impact of videogames on medical training of students, physicians and even patients. While in the second part the way of using computer games in healthcare is discussed. For example, they can be used in the therapy of children diagnosed with autism spectrum disorder or cerebral palsy, also as a way of reducing pain or discovering new biochemical structures. The intention is to cover, apart from gaming, also related technology like virtual reality and augmented intelligence which even enhances the experience of medical training or usage in healthcare.

KEY WORDS

Video games, medical training, virtual reality, augmented intelligence, healthcare, medicine, laparoscopy, acupuncture, autism spectrum disorder, AIDS, cerebral palsy

ANOTACE

Tato bakalářská práce se zabývá možným využitím počítačových her a technologiemi s nimi spojených v rámci medicínského vzdělávání a zdravotní péči. Veřejnost často vnímá videohry jako ztrátu času, nebo je využívají pouze pro zábavu. Cílem této práce je proto prokázat jejich využitelnost a pozitivní vliv na již zmínění medicínský vzdělání a zdravotní péči. První část práce pojednává o vlivu her na vzdělávání studentů medicíny, lékařů i pacientů a zároveň jej kriticky analyzuje. Druhá část je zaměřena na využití her ve zdravotní péči, jako je například terapie dětí s autismem nebo dětskou mozkovou obrnou, dále jako možnost redukování bolesti, či způsob objevování nových biochemických látek a struktur. Záměrem práce je zabývat se nejen počítačovými hrami, ale také s nimi spojenými technologiemi jako je virtuální a rozšířená realita, které ještě násobí zkušenosti získané v medicínském vzdělání.

KLÍČOVÁ SLOVA

Počítačové hry, medicínské vzdělání, virtuální realita, rozšířená realita, zdravotní péče, medicína, laparoskopie, akupunktura, autismus, AIDS, dětská mozková obrna

BIBLIOGRAPHIC QUOTATION

GÁLÍKOVÁ, Markéta. *The Role of Video Games in Health Care and Medical Training*. Brno, 2019. Available at: https://www.vutbr.cz/studenti/zav-prace/detail/119382. Bachelor thesis. Brno University of Technology, Faculty of Electrical Engineering and Communication, Department of Languages. Supervisor Magdalena Šedrlová.

BIBLIOGRAFICKÁ CITACE

GÁLÍKOVÁ, Markéta. *Využití počítačových her v medicíně*. Brno, 2019. Dostupné také z: https://www.vutbr.cz/studenti/zav-prace/detail/119382. Bakalářská práce. Vysoké učení technické v Brně, Fakulta elektrotechniky a komunikačních technologií, Ústav jazyků. Vedoucí práce Magdalena Šedrlová.

SWORN STATEMENT

I hereby declare that I am the sole author of this bachelor thesis, which deals with the topic of Video Games in Medical Training and Health Care. I have worked out this thesis under the supervision of my supervisor Mgr. Magdalena Šedrlová and that I have not used any sources and literature other than those listed in the references.

Further I declare that I have not violate any right of others in connection with creation of this bachelor thesis. I have not infringed any copyrights and I am fully aware of consequences leading from violation of copyright law Regulation S 11 and the following of the Copyright Act No 121/2000 Sb., and of the rights related to intellectual property right and changes in some Acts (Intellectual Property Act) and formulated in later regulations, inclusive of the possible consequences resulting from the provisions of Criminal Act No 40/2009 Sb., and of the rights related to intellectual property right and changes in some Acts (Intellectual Property Act) and formulated in later regulations, inclusive of the possible consequences resulting from the provisions of Criminal Act No 40/2009 Sb., Section 2, Head VI, Part 4.

In Brno May 27th 2019   …………………….....

                                                                            Author signature

ACKNOWLEDGEMENT

I wish to express my sincere thanks to my thesis supervisor Mgr. Magdalena Šedrlová for providing me with all the necessary consultations and for her valuable guidance and encouragement extended to me during the preparation of my bachelor thesis. This accomplishment would not have ever been possible without her.

In Brno May 27th 2019 ....

Author signature

TABLE OF CONTENT

INTRODUCTION

Video games are known to be a way of fulfilling free time. From the technical point of view, it is considered as an interaction of a user (player) and a computer software particularly designed to provide a way of escaping from the reality, to provide relaxation. Some games might be created for educational purposes, but the main purpose is to entertain. Games are now part of modern life, children are not the only playing group as might be assumed, there are many professional players among all generations, for instance in America the average male player is 32 years old and female is 36. 64% of American households own a gaming device ("Essential Facts About the Computer and Video Game Industry", 2018). Huge amount of money is being invested into game industry which leads to the further development of video games and continuous creation of new ones. Sci-fi, strategies, action, or logical games are only a few examples of many different genres and topics existing within the gaming world. Gaming attracts more and more people, players are spending hours of practicing one role in a particular game to become the best in the world. In the last decade playing has evolved into electronic e-sport, where teams of professional players compete against each other. Furthermore, for the best of them gaming became a serious way of making a living.

There are multiple ways of playing, it is possible to play offline only on your own, as well as online with multiple players at once. Modern technology allows us to choose among a variety of devices, from personal computers to handheld consoles, television consoles, and smartphones, which are the most used device for gaming. ("Video Gaming Industry Overview", 2018) In addition, outdated storage devices such as floppy discs or compact discs are no longer needed as a transfer medium, because gaming platforms like Steam, Uplay or Origin exist, where players can buy, download, update and mainly play games of all kinds. The trend of the last years is to support the development of virtual reality, which offers many various and useful ways of applications apart from gaming, for example simulations of surgery, training simulations, etc.

The attitude toward games, in the recent years, has been rather negative. It is believed that games contribute to obesity and action games create aggression mainly within the young and adolescent generation. Thus, some genres of video games such as first-person perspective shooting games, regarded as those provoking aggression and violence, are

age-limited. Some studies also indicate that gaming enhances the risk of obesity with every played hour. Probably the most dangerous aspect of video games is tendency to become a cyber drug. (Hymas & Dodds, 2018) However, games are not only used to influence minds in a negative way. Some of them are designed to improve memorising ability, others help to develop cognitive, or logical skills, contribute to obesity reduction, and in addition virtual reality might be utilised as a painkiller. (Reader's digest) Those games are referred to as serious games or games created for different than purely entertaining purposes. One of games sub categories is called exer-games, in other words, games designed to improve mental abilities and health.

My bachelor thesis deals with a possible use of video games and related technology in medical training and healthcare. The possible ways of usage and experience gained through the video games will be investigated. Moreover, their impact and usefulness will be analysed. The thesis will be divided into two main parts. First one will focus on methods used in the education of medical students as well as training possibilities for physicians, or other experts in the field of medicine. The thesis will also deal with virtual reality and its innovative approach to display human anatomy. The second part will focus on the patient, possible implementations in health care will be discussed and presented. Several ways of usage will be discussed, for example ways of rehabilitation for children suffering with autism or cerebral palsy as well as for stroke survivors. Furthermore, the paper will deal with games as a way or reducing pain.

The aim of this thesis is to provide an overview of possible utilizations, and to illustrate in ways in which are the serious games used. The goal of the thesis is also to critically analyse the impact of video games and gaming technology with the focus on the physicians (medical training) and the patient (healthcare).

1. VIDEO GAMES IN MEDICAL TRAINING

Generally, technology affects the way the learning is done today. Pupils are using the internet to reach information, tablets are utilized in classrooms, interactive and logical games are played. Medicine studies require long-term dedication and it is very demanding task to do. The number of information that students are required to learn is enormous. Medical students often spend many days learning from books to prepare for exams, which might be considered as boring and memorizing by heart does not always work. To provide better imagination, the virtual reality and animations are used for learning the anatomy of organs, bones and the human body itself. Especially video games might be a way to make the learning a bit easier and unquestionably more fun. Of course, it is probably impossible to cover all the medical syllabus, but that is not even intended. The main goal is to make the studies accessible, easier to remember and to keep the information in the memory for a long time.

Medical students and physicians do not have to use only specially designed medical games and simulators to improve in their field, ordinary video games may also be useful. The report published in the Archives of Surgery in 2007 claims that surgeons playing video games more than 3 hours per week make 37% fewer errors in laparoscopy than their colleagues who do not play videogames at all. (Miller, 2018)

1.1. MICROBE INVADER

Microbe invader is a role-playing browser video game where players are put into a hospital community, where they as a medical student treat people living in the town and patients in the hospital. It was created by Li Thao, from the Case Western Reserve University School of Medicine in Ohio, the USA. About 89 different pathogens occur in this game, including bacteria, viruses, fungi, and parasites, which can be cured by 43 different types of antibiotics. This game is designed to help with learning of microbiology. The task of the player is to carry out necessary examinations to be able to diagnose symptoms and consequently cure the disease with the proper type of antibiotics. The game provides complex behaviour of pathogens causing antibiotics resistance and even side effects of the treatment. Some pathogens are connected to a certain place or appear in given circumstances as they usually do in reality, in this case,

the game is as realistic as possible and helps to learn about possible issues students of medicine can encounter during their studies or later in general practice. (Tao)

This game is not only about guessing the correct answer, in the case the judgement of treatment is wrong players are advised to go to a library to do further research. In addition, a notebook is written during the play-time consisting of correct treatment ways and important information, thus it is not necessary to make notes and the player can always learn and revise from it. Despite the lack of available precise data, according to the user feedback the game seems to be useful tool to learn microbiology in an entertaining way and widely used by medical students mainly coming from English speaking world. (Tao, a)

Although the game does not have a very wide player base, only about 400 according to official Facebook page of the game. It proved itself to be very useful considering user feedback. Rechel Zettl shared his experience "Hi! Your game is amazing! I literally use it to study for my NBME exams for each class. I'm an MS2 and I absolutely love it. […] Thank you so much for making this game, it has been so helpful!" (2014) as well as CJ Quach „This game saved my micro board score! <3". (2013) More than 50% (12/23) of people leaving feedback were provably students of medicine, microbiology, or working as physicians. Unfortunately, the last update was adapted on 1st April 2014.

1.2. PROGNOSIS

Prognosis is the video game based on clinical cases, which are created on the basis of more than 600 real-life scenarios, which have been reviewed by more than 150 specialists from all over the world. New stories are continuously added into the game. It is free to play and available in the browser, or smartphone devices. It is widely used by physicians, medical students and nurses from 195 countries of the world, has over 5 million downloads and it has been constantly ranked as one of the ten best medical games. In the USA it even reached 1st place. (Medical Joyworks LLC, 2010)

Every case is described in detail to provide the player with sufficient amount of information necessary to understand given symptoms. Players are proposed various investigation methods such as X-ray, colonoscopy, blood count and many others according to the given case, and their task is to decide which of those examinations are necessary to be performed and which are irrelevant. After the chosen investigating

methods are executed, the player obtains detailed results about the symptoms, or injuries. The relevant way of treatment is consequently about to be estimated. After closing the whole case a summary report can be displayed, which provides commentary of individual steps along with further details of investigating methods, appropriate solutions to given case and additional information about symptoms and possible complications. (Medical Joyworks, 2010)

Referring to a user feedback, comments added by the people from the field of medicine and nursery have been mostly positive apart from some technical issues, which are irrelevant for this work. Vera Lupe in her amazon review says:

"This is an amazing app, it helps you develop a critical approach towards patients. The app offers an extended number of cases in different areas of the medical field, assuring that you won't get stuck with the same cases since it updates with new cases very often. To me though, the greatest part is the discussion of the case once you're done performing; in this section players can find a detailed explanation of the case, the condition, differential diagnosis, treatments, etc. Well, not to get you tired, you have to try it. Prognosis is a great way to learn new things and to put in practice what you already know, let's treat patients!" (2012)

On the other hand, uninstructed users often complained about the game being demanding and hard to comprehend. Despite the game being published in 2011, developers are adding more and more cases keeping the game updated. Using the platform of mobile and tablet devices makes the game available everywhere, every time resulting in a huge number of players all over the world.

1.3. NIGHT SHIFT

The National Academy of Medicine states in the 2015 report *Improving Diagnosis in Health Care* that every individual in the United States will experience at least one diagnostic error during his or her lifetime. (Mohan, Schell, & Angus, 2016) Due to complexity of medicine, lack of information in health care and patients with their inability to describe all the symptoms in detail, as well as individual development of disease, it is very difficult to estimate exact medical therapy and human error can occur. Coming to the physician in time is the key factor. This risk of error increases especially in the situations where there is lack of time for decision making, for instance at emergency departments in hospitals, where physicians fight in severe cases, for every second, which can make the difference between life and death. The University of Pittsburgh School of Medicine together with Schell Games, educational and entertaining game development

company, were looking for a way of reducing diagnostic errors made by doctors and physicians in hospital Emergency Departments. This game does not focus on medical students but rather on physicians already working in hospitals, it targets their decision making, heuristics (intuitive judgements) and makes the player re-evaluate the approach to patient´s trauma.

In collaboration with emergency medicine physicians, trauma surgeons, behavioural scientists and game designers, a video game the Night Shift was created. The point-and-tap adventure game is free to play. The player is placed in the role of Andy Jordan, an emergency medicine physician in an East Coast town, who faces critical care situations. ("Night Shift") The learning is done in the way of character-driven dialogue trees. The game is designed to focus on critical decision making and risk recognition. The plot deals with the relation of Andy and his grandfather who passed away in a peculiar way. The gamer is about to go through the hospital in the East Coast town, talks to patients and observes information about their symptoms and treats them according to his knowledge and heuristics. At the same time the player discovers more details about his grandfather´s life as some of the patients and some of hospital employees knew him. This way the player sympathizes with the played character, gets emotionally engaged in the story and all together with that assesses the patient's need for urgent care dealing with different types of injury severities. (Kotaku, 2018)

In order to prove the efficiency of learning through computer games to the detriment of traditional learning procedures a clinical trial has been done at the University of Pittsburgh. The game - Night Shift and traditional didactic papers - *myATLS* and *Trauma Life Support MCQ Review* were compared. 368 medicine physicians, who work at non-trauma centres were participating for six months, they were split into 2 groups one being exposed to the game and another to the didactic learning. The focus was given to decisions involving trauma triage cases, where physicians use the intuitive judgement the most. This unconsciously triggered behaviour is yet to be further studied, as it is very little known about its function. Scientists were investigating mainly two kinds of mental processes, first – fast, automatic, and heuristic, second – slow, deliberate, and analytic. (Kahneman, 2012). Physicians under the pressure tend to use mainly the set of first mentioned, which may cause errors or overlooking of some important aspects. Examination on physicians' decisive ability whether to discharge or transfer the patient

to a trauma center was measured after the launch of the study (primary outcome) and after six months during which participants have been exposed to a given way of education (follow-up study). As a secondary outcome the influence of cognitive load on under-triage was examined. Participants who were exposed to the video game (149 participants) were less likely to under-triage severity of patient´s injury, they made a mistake in 316 of 596 cases (53%), while those taking didactic education (148 participants) were less accurate failing in 377 of 592 cases (64%), making 11% difference. After six months when the experiment was repeated the difference increased to 17% being 146 of 256 for gamers (57%) and 172 of 232 for didactic learners (74%) (see tab. 1). Gamers estimated the 95% confidence rating from 5% to 16%, while for non-gamers this interval was from 9% to 25%.

Tab.1.3.-1. Physicians decisive ability in emergency departments

		patients	under triaged	triaged	failure	success
gamers	beginning	596	316	280	53.02%	46.98%
	after 6 months	256	146	110	57.03%	42.97%
non-gamers	beginning	592	377	215	63.68%	36.32%
	after 6 months	232	172	60	74.14%	25.86%

(data extracted from Mohan et al. report)

As given numbers suggest, the accuracy of judgement for physicians who played the game decreased only by 4% while for non-playing physicians dropped by 10%. On the other hand, the follow-up study did not prove that any cognitive load, or mental effort employed in the working memory, would significantly influence under-triage of patients, regarding the results of 161/308 (52%) at the beginning and 155/288 (54%) after 6 months for gamers, and 197/300 (66%) to 180/292 (62%) for non-gamers (see tab. 2). (Mohan et al)

Tab.1.3.-2. Influence of cognitive load on decision making

		patients	under triaged	triaged	failure	success
gamers	beginning	308	161	147	52.27%	47.73%
	after 6 months	288	155	133	53.82%	46.18%
non-gamers	beginning	300	197	103	65.67%	34.33%
	after 6 months	292	180	112	61.64%	38.36%

(data extracted from Mohan et al. report)

2. VIRTUAL REALITY IN MEDICAL TRAINING

Human perception of reality can be seen as combinations of information which flow through our senses and which are processed by the brain. Our senses adapt to the given impulses and thus we feel present in a reality we are currently experiencing no matter whether the reality is generated by a computer or it is the real world. The virtual reality may be achieved once human senses are exposed to the stimuli from the devices providing us the illusion of reality, or in other words of three-dimensional computer-generated environment. These devices may consist of headsets, omni-directional treadmills and special gloves. Movement of the body can be scanned and simulated into virtual reality which player perceives. Actually, the human senses are more complex, thus able to recognize computer simulation. In addition, human vision rate is 180°, which is more than degree of vision displayed by the device screen. In addition our peripheral vision must be taken in consideration, which cannot be displayed by the technology yet. Moreover, when our view is in collision with our hearing it might cause motion sickness. For these reasons, the simulation must be done properly to be effective and as real as possible.

Virtual reality has many possible uses apart from medical ones, examples are flying simulators for pilots, training simulators, educational applications, architecture modelling and of course the entertainment. However, this thesis deals with medicine and health care, the field in which the virtual reality has gone through significant development. It is used as a tool for learning surgery, it enables students and physicians to examine body organs without extracting them from human body simply as thee-dimensional pictures. The advantage of virtual reality is that the surgeries can be performed many times repeatedly, which is in ordinary practice limited by the number of bodies available for medical training. (Virtual Reality Society)

2.1. BIODIGITAL

Probably the majority of medical students would consider the exam from anatomy as one of the hardest. The human body consists of many types of cells which are composed into bones, muscles, organs, and tissues, everything within the human body has its specific function, shape, position and one act influences the other. Students are required to learn all those relations even with possible malfunctions and variances. It also requires

a portion of imagination as the parts of the body are usually displayed from one or two angles. Fortunately, technology improved enough to allow the human body to be scanned into a virtual reality.

BioDigital Inc. is a biomedical company established in 2002 with the idea that 3D visualization may change the way medical education is done. In 2011 web-based virtual model of the human body was introduced. Launched on 6th January 2014 for iOS devices the application of BioDigital 3D Human Anatomy continues in its improvement until today. This application is widely referred to as the Google Map of human body. It is free 3D model software available at all mobile device platforms and also in internet browsers. It consists of complete scientifically verified assembly of male and female human body, which can be displayed in whole or by parts. It is also available on the platform of Google Cardboard which enables user to enter the virtual reality. User can focus on individual anatomy models like organs, muscles and their tendrils, whole body parts or anatomy systems such as digestive, nervous, and skeletal systems. In addition, this software can display what it looks like inside a human body during different stages of disease or others malicious health conditions such as cancer, diabetes or heart disease. (BioDigital Inc., 2011) Users can create their own library of objects. There are more than 6,000 anatomic objects to observe also provided with the detailed medical description and the application is used by more than 3,000 schools for education of their students, including the Charles University of Prague. (BioDigital Inc., 2011a) The application also allows to test the knowledge by the means of a quiz. Furthermore, patients can easily discover the core of their problems after the consultation with specialist and reach further understanding of their condition thanks to the online availability. The BioDigital Human received many recognitions in worldwide media as well as awards for their contribution in the field of science namely: the SXSW Classic Interactive Award in 2013, the Webby Award for the Best Health Website in 2015 and became a Silver Finalist for the Edison Awards in 2015 in the field of Research and Education. ("BioDigital")

The same company developed in 2016 the Craniofacial Interactive Virtual Assistant Pro (CIVA Pro), in cooperation with non-profit organisation myFace, Institute of Reconstructive Plastic Surgery and the Department of Plastic Surgery at NYU Langone Medical Center. Basically, it is an interactive surgical simulation platform, which leads the surgeon by the discrete steps through the ten mostly used surgical procedures. The

application is designed to provide sufficient didactic value to professionals, to their patients and also relatives. Moreover, educational videos, images, voice-overs and 3D labels are attached to provide user with additional information or to illustrate ordinary real-world procedures together with pre and post-operative care. It is validated by the experienced professionals and supported by people who experienced some facial deformation themselves.

The main idea of this project is to create popular awareness about the topic of facial reconstructive surgeries, but mainly to ensure the further education of surgeons specialising in the field of reconstructive and plastic surgery. Surgeons and medical physicians from 74 countries are using CIVA Pro software in order to prepare for the surgery in the best possible way. The aim is also to provide medical students with a useful tool for practice and study. (myFace, 2017)

2.2. LAPAROSCOPY TRAINING

Laparoscopy is a kind of surgical procedure which is done through small telescopes, called laparoscopes, equipped with light source and small camera which enables surgeons to see what they are doing. It is minimally invasive surgery because it does not require to open the body, only small incisions are necessary for laparoscopes to be inserted. This kind of surgery lowers postoperative pain, shortens the recovery time and injure fewer particular muscles, nerves, and skin. (The Editors of Encyclopaedia Britannica, 1998)

However, the surgeons have to be well instructed, sufficiently trained, be aware of human anatomy, be able to manipulate with laparoscopic tools precisely and have good eye-hand coordination. Due to virtual reality and computer simulations the necessary training may be achieved on several devices like LAPARO ASPIRE, LAPARO ADVANCE LAP Mentor II, Abc-lap, or Simbionix Lap Mentor. ("LAPARO Medical Simulators", 2016) Majority of those laparoscopic trainers consist of laparoscopic instruments (scissors, grasper, dissector), several training modules for practicing methods used during laparoscopic surgery and some cover of the operating field which is than displayed on the monitor screen or in VR (some devices enable to perform the training under direct eye control, which is suitable for beginners).

Short-term use of the Simbionix Lap Mentor, laparoscopic VR simulator, was surveyed for two weeks. Fifteen respondents used the simulator in average 95 minutes per two weeks. 10 users completed pre- and post-simulator surveys, in order to report its utilization and gained experience. The survey proved several features of virtual laparoscopic training: 66,7% of respondents reported the benefit of experiencing real-life cases, on the other hand, 90% of them referred to the lack of tactile feedback as a disadvantage. The brief period of use did not prove any improvement in the field of laparoscopic skills of respondents, in fact they find it to be less useful than expected. (Changchien, Tawfik, & Kukreja)

At the Université Laval in Quebec, Canada the second generation of Simbionix Lap Mentor was tested in long-term training. The aim of comparative study was to ask testing subjects to attend two sessions on LAP Mentor II. Each session consisted of 5 consecutive repetitions of 9 basic laparoscopic tasks. The participants were divided into 2 groups according to their previous skills: junior and senior residents (graduate medical students, who gain their experience under the supervision of senior clinician). Junior residents proved themselves to be more accurate and faster in 2nd session compared to the first one, in general their performance improved a lot. Senior residents, who already had an experience in the field of laparoscopy, noticed improvement in execution time with camera manipulation and eye-hand coordination. (Paquette, Lemyre, Vachon-Marceau, Bujold, & Maheux-Lacroix, 2017)

Unfortunately, the laparoscopic simulators are quite expensive and usually accessible only at institution specializing in the field of laparoscopic surgery. In order to change this, Open Simulation company is currently working on a low-cost simulator LapKit compatible with mobile phones. The idea is to train 2.2 millions of medical experts world-wide to provide sufficient medical care to everyone. All the simulation is done on the mobile screen, which is connected with laparoscopes and tracks their movement. All data are stored in application and user is shown precise time of the practice together with accuracy, and errors. The laparoscopic simulator is still in development since 2016 and it is not yet known when it is about to be finished. ("Open Simulation", 2016)

3. AUGMENTED INTELLIGENCE IN MEDICAL TRAINING

Augmented intelligence or augmented reality (AR) is the implementation of artificial intelligence (AI), which focuses mainly on the assistive role of AI. The aim is not to replace human intelligence but to enhance it, especially while using learning and problem-solving skills. In the field of medical training and health care AI algorithms can be used to analyse patient's symptoms and health information which are afterwards compared with previous diagnoses of given person, medical data of his/her family, or data available within population. It can provide the physician with suggestions on patient's possible issues and treatment. This action would take ages to a person while for AR it is the matter of seconds. (Dickson, 2017)

3.1. ACUPUNCTURE VR TRAINING

Acupuncture is associated with ancient Chinese technique for restoring harmony and health in the human body, it is also known as a way of relieving pain. It is based on the philosophy of jin and yang, which are supposed to coexist in the harmony next to each other. The imbalance of these two elements results in pain and disease, causing the disgruntlement of life force qi. Qi flows through 12 pathways in human body, those lines are associated with major visceral organs or body system. Acupuncture affects the distribution of jin and yang in those 12 basic meridians and therefore enables qi to flow through our body. In practice acupuncture means inserting small needles into precise acu-points of given depth located over 12 meridians. (The Editors of Encyclopaedia Britannica, 1998a)

Acupuncture includes some kind of danger, practitioners are undertaking a risk while needling points close to important organs or nerves. Unsteady hand as well as wrong depth or angle of insertion may cause bad consequences. Students have to study human anatomy and changes in body caused by the needling. The virtual reality in combination with augmented intelligence allows students of acupuncture to work with human body without being afraid of hurting anyone. In VR student can flow through the human body the way qi does, observe responses of tissue to inserting needles and in addition observe the human body together with all its organs, veins, functional systems accessible through the visualisation of human body called BodyMap. (Augmented Intelligence, 2018)

Individual muscles, vessels are labelled to provide educational value. This technology has already been implemented at Beijing University of Chinese Medicine, where it is currently going through the testing stage. In case of proving itself useful it is about to be introduced to all 29 Chinese universities of Chinese medicine. (Yau, 2018)

4. VIDEO GAMES IN HEALTH CARE

Health care is a very complex field involving many people taking care of patients with different diagnoses and symptoms. In healthcare the clinicians are trying to establish and perform a treatment or rehabilitation which would be the most suitable for the given patient. Technology brings many possible ways how to enhance the methods and make the treatment as efficient as possible. Serious games, or games designed with different purpose than entertainment are one of the possibilities how to implement technology into medicine. Although general public may consider video games as a waste of time without any educational value and believes that it is only a way to entertain yourself, the games provide multiple ways how to improve health, for example by encouraging people to exercise, but also learn about illnesses. For this reason, the Games for Health Project was established in 2004 combining knowledge of game designers, medical professionals and researches. Number of clinical studies on the topic of not only computer games, but also gaming technology has been carried out and certainly many more will occur in the future.

4.1. AFTER-BRAIN INJURY RECOVERY

Human brain is one of the most important organs in human body, it is part of the central nervous system together with spinal cord. The brain is the most complex organ, includes about 100 billion neurons and consumes around 20 % of energy and oxygen of human body. Our brain conducts both physical and mental activities. The very basic division of the brain is into four lobes: temporal which is important for emotions, long-term memory; occipital for visual processes; parietal lobe which responds to sense impulses, and also provides spatial orientation and language; and frontal lobe where processes of attention, motivation and short-term memory take place (Newman, 2017). As illustrated brain is the essential part of every process happening within human body and therefore any injury or illness can lead to permanent consequences. Any damage caused by force or in other words brain tissue deformation caused by the crash of brain to the skull is noted as a traumatic brain injury. This way several neuron cells can die or be permanently damaged, the same effect causes the stroke, when a vain burst and a part of a brain is flooded by blood and cells die for the lack of the oxygen. Due to those harms humans can lose control over muscles, loss memory, or suffer from other kinds of disabilities. However, brain´s neuroplasticity has been proven for many years, it has the

ability to create new neuron connections and rebuilt its tissue. People are advised to play games as a rehabilitation in order to regain fine motor skills, spatial recognition and cognitive functions, those games can be card games, or sudoku, nevertheless with the advanced technology virtual games became the trend for after-brain injury and stroke rehabilitation (Stasio).

4.1.1. LUMINOSITY

One of those games is Lumosity a set of many games divided into several categories such as speed of processing, memory, attention, problem solving, vocabulary, Math, or ability to switch between tasks. This free to play app is able to adapt to needs of particular player/patient no matter the age or education. After 10 years of operating the Lumosity reports about 95 million players, their goal is not only to provide brain training to everyone but also to focus and broaden the knowledge of cognitive training, participating in *The Human Cognition Project* (Lumos Labs, Inc.). In cooperation with scientists from over 40 universities a study was carried out on the topic of *Enhancing Cognitive Abilities with Comprehensive Training: A Large, Online, Randomized, Active-Controlled Trial* where a group of 4,715 participants were divided into two groups. The first group was instructed to take 15-minute long sessions at least 5 days per week playing games in Luminosity, while the second group was completing crossword puzzles for the same period of time. The result of the study shows a significant improvement of neuropsychological performance of the first group playing online games. Speed of processing, short-term memory, working memory, problem solving, and fluid reasoning assessment improvement was reported together with better concentration. (Hardy et al., 2015)

4.1.2. THERAPPY

Since the Luminosity targets people of all categories and is not originally designed for stroke and brain-injury rehabilitation, it can be easily used for this purpose. On the other hand, the Therappy application is specially designed to help survivors with brain recovery and rehabilitation. In cooperation with National Health Service, the Therappy team (composed of physiotherapists, nurses, psychologists and other clinicians and also patients) tests applications designed for victims of stroke and brain injuries, rates them on a 50-point scale and divides them into categories according to their main purpose. Motoric skills, memory, or vision enhancements are few examples of the possible

utilizations, moreover the application offers pain and activity records, helps with maintaining eating and drinking habits. In addition, an interface for clinicians is provided, where the focus is given to occupational health of physicians, it can also serve as an information source for both patients and their families. Since those applications are available on tablets and smartphones it allows home therapy as well as sessions in hospitals. However, their purpose is to be additional tool, they are not intended to replace treatment. ("MyTherappy")

4.1. PREVENTING DISEASES

4.1.1. FOLDIT

Human body is made of trillions of cells, those cells are made up by proteins, their role is to ensure the operation of cells and therefore whole human body. Protein is organic molecule consisting of amino acids (small molecules created by atoms of carbon, oxygen, nitrogen, sulphur, and hydrogen) joined together into long chains numbering from 100 to 1000. The composition of different amino acids determines the function of the protein itself. There are 20 different kinds of amino acids differing by the different patterns of atoms inside. Proteins fold into different shapes defining its function and purpose within the body. (The Editors of Encyclopaedia Britannica, 1998b)

The idea behind the game is to collect huge amount of data crated by players and afterwards verify their usefulness. The main goal it to fold proteins like virtual abstract 3D puzzle into different shapes and structures. The game was developed by the University of Washington and firstly released in 2008. Since then 736,553 accounts have been registered worldwide, however this number includes also inactive players. ("FoldIt: Solve Puzzle for Science"). It has been proved that gaming develops special reasoning skills, which is the ability necessary for folding proteins and which computers are not very good at. Motivation to play is very simple, to contribute to the scientific research and help to discover a cure for serious diseases like cancer, the Alzheimer disease and AIDS. The game itself evaluates how good proteins designed by the player are.

The contribution of players of small or no education in the field of biochemistry has proved itself very useful. By generating huge number of protein designs scientist collected data which would never be possible to achieve through research or by computer generation, in addition protein shape predictions are very slow and expensive. On 18th

September 2011 in *Nature structural & Molecular Biology* a report was published providing the evidence of gamers´ contribution to resolving the structure of retroviral protease. This enzyme is the key protein in the process of multiplication of HIV and players were able to design it within 10 days of playing FoldIt (J. Coren, 2011.) Gamers were able to model a protein structure of such a good quality that scientists from Washington University were able to design an antiretroviral drug in three weeks, which blocks the multiplication of enzymes (Armstrong Moore, 2011).

5. VIRTUAL REALITY IN HEALTH CARE
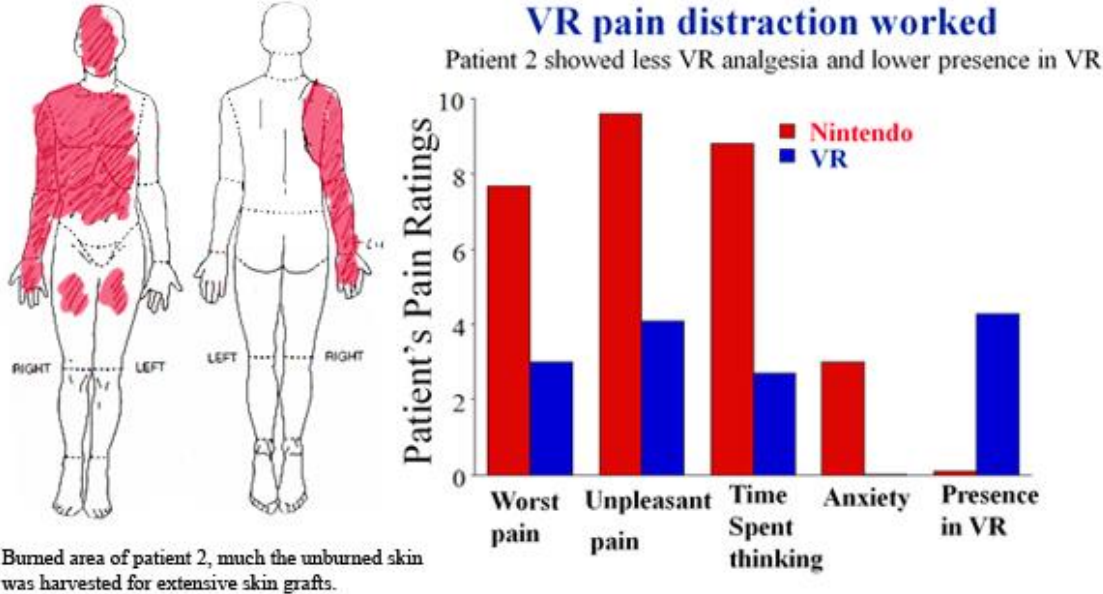
5.1. PAIN REDUCTION

Pain is considered as a warning mechanism, which is mostly caused by the physical injury, but it can also be of the psychosomatic origin. Sometimes even the pain occurs without any particular reason, these states are called chronic pain and it is very often present with serious diseases such as cancer or arthritis. This state can even be enhanced or connected with the mental state of mind, especially with negative emotion like depression. Every person has different pain tolerance, meaning that each person can withstand or ignore the pain to a certain level. Pain is designed to alert the human body that something is not right and notify person to take the action against the harmful stimulus. The feeling of pain is a result of treatment of painful impulse which is detected by the pain receptors and subsequently sent to the brain, where it has been processed. (The Editors of Encyclopaedia Britannica, 1998c) It was discovered that painful impulse attracts a big amount of attention, makes the patient focus on the pain itself and this way the pain gets worse.

When the pain is to be reduced painkillers or opiates are utilised, this method restricts the synapsis in the brain transmitting the information about the pain, the feeling of pain is limited or even completely disappears – the painful impulse is still present, but the feeling of pain is ignored. In some extreme cases even, the strongest opiates are not enough to muffle the pain. A research consisting of virtual reality (VR) has been carried out studying burned patients. In the University of Washington Harborview Burn Centre the virtual-reality game called SnowWorld was developed. The game was designed as snowy environment the opposite to the fire which patients went through. The point of this game is to make patient completely focused on the exploration of frozen world, throwing snowballs to snowmen and penguins or watching mammoths, while nurses exchange bandages, remove staples, clean wound or patient taking the therapy, extremely painful but daily routine for burned patients, especially kids. The aim of this VR game is to draw as much patient´s attention as possible and limit the way he/she focuses on the pain itself and therefore reduce the feeling of pain. (Gramza, 2008)

In a case study the patient with severe burn covering over 33% of his body was examined. He was asked to rate his pain after some staples of his skin had been taken

while playing on Nintendo and other staples from the same area were removed while playing SnowWorld in virtual reality.

Fig. 5.1.-1. Patient´s Pain Rating

(data extracted from "VRpain" webpage)

As shown in the graph patient stated huge pain reduction while playing in VR. In this particular case, the worst pain was reduced by 62,5% compared with playing the Nintendo, while unpleasant pain decreased by 60%, in other cases the number or pain reduction oscillates from 40% to 50% in average. Unfortunately, there have not been many case studies of this kind done yet, but it can be certainly said that virtual reality is the possible way of reducing and treating acute or chronical pain. ("VRpain")

6. THERAPY FOR CHILDREN WITH ASD AND CP

6.1. GAMES FOR CHILDREN WITH AUTISM

Autism or Autism Spectrum Disorder (ASD) is a developmental disorder which affects physical, social and language skills. The symptoms as repetitive abnormalities in social interaction, communication, or behavioural irregularities appear during the first years of life. Examples of signs of problems in social communication can be inability to maintain eye contact, difficulty in establishing relationships; in communication for example delayed spoken language or narrow range of facial expressions. People with autism tend to focus on parts rather than whole objects, they need to get used to their routine and familiar surrounding where they feel safe, otherwise they may be agitated or even furious. (The Editors of Encyclopaedia Britannica, 1998d)

Autism is not only one type of disorder, it is highly individual, and each person has different set of strengths and challenges. Some might be genial in Mathematics, whereas unable to maintain eye contact or express themselves in words. According to Centers for Disease Control and Prevention 1 out of 88 children is diagnosed with autism, where girls are four times less likely to be affected. (Autism Speaks Inc.) There is no cure for autism, on the other hand, it has been proved that early therapy contributes to the minimalization of negative effects and allow people to be independent in adulthood. Technology offers an accessible way to provide a therapy for everyone from the comfort of home.

6.1.1.   FACESAY

FaceSay is a computer game designed to improve social communication skills, more specifically assign facial expressions to particular moods and emotions. The aim of the game is to generalize the everyday experience which might seem awkward to children diagnosed with autism and make those situations familiar. A player (affected child) follows for example a gaze of person on the screen and tags things he/she is looking at, and therefore learns to follow sights in real-life experience, or in a different mode merges together a face which is split into several parts and in wring order. Several control studies have been done providing the evidence of the real impact of the game, kids were able to read and recognize facial expressions and even initiate the social interaction on their own ("FaceSay: Social Skills Software Games").

In the study *Computer-Assisted Face Processing Instruction Improves Emotion Recognition, Mentalizing, and Social Skills in Students with ASD* published in 2015 the positive impact of FaceSay on recognition, mentalizing, and social skills has been proven. School children undergoing 12 sessions reported better recognition of basic emotions such as happiness, sadness, neutrality, anger, disgust and fear. In addition, they also noted improvement in understanding of other´s feeling, ideas or thoughts and comprehension of their own emotions, feelings. They were also able to recognize lies, pretending and deluding. All those achievements corresponded to decreasing number of autism symptoms. Moreover, FaceSay demonstrated its helpfulness and prove itself to be the tool to improve social communication, mainly facial recognition skills, joint attention bids, eye contact, and ability to distinguish different emotions. However, this study did not prove any improvement nor deterioration of social interaction in prosocial behaviour, which needs more social interaction that goes beyond the areas FaceSay focuses on. (Rice, Wall, Fogel, & Shic, 2015)

6.1.2. LET´S FACE IT

The project Let´s Face It set in cooperation of University of Victoria study program of the Cognitive and Brain Sciences and the Yale Child Study Centre has the same ambition as FaceSay, to provide a way to teach children with autism spectrum disorder face processing skills. The focus is given to four main categories: understanding of facial structure and response to faces, recognition of facial identity, interpretation of emotions and finally perception of the meaning of facial changes and their comprehension. The aim of this project was to create interface for children with autism and specialized learning needs in cooperation with research findings of psychology and neuroscience. Furthermore, players (children) can create their own content and customize the interface to correspond to their own needs. In contrary to FaceSay, this software is completely free, and its creators believe that it should be available to everyone. ("Let´s Face It")

 In addition, creators also developed the project FaceMaze. The goal of this project is to teach children with autism to fit into society, where smiling is a convention in some degree. Researchers tried to train children to provide desired and convincing facial expressions. To achieve that, the game is designed to navigate a figure like Pac-Man through the maze to gather candies by smiling or glowering long enough to fill up a smile-o-meter. Player is recorded by face-recognition system and judged in real-time.

40 children were tested, 17 of which were diagnosed with ASD, their sad, happy or surprised expressions were recorder before and after playing the maze game and consequently rated. As the result of this study children with autism provided more convincing happy or angry expression after playing the game, comparing to those taken before playing. On the other hand, the surprised expression had not been improved because it was not required in the game. Unfortunately, projection to spontaneous reactions was not tested, and therefore the study does not show any contribution to real life. However, it might be argued about the ethnical point of forcing children with autism to fit into the society. (Wright, 2014)

6.1.3.   THE SIMS

Specially designed games or serious games are not the only branch of games used for therapeutic purposes, basically any game where social relationships are simulated can serve the desired purpose. One of those examples is The Sims, where children affected by autism can create characters or entire families, watch them interact together in everyday process, create their own relations and even engage their actions. The game is based on Maslow´s psychological approach of hierarchy of needs, where every character has its needs and ambitions. Specially designed mods are available, which add custom trait of ASD which can be applied to the sim (game character) and simulates everyday life of a person with Autism Spectrum Disorder. This mod with almost 45 thousand downloads was created by user Piebaldfawn who is diagnosed with autism. (piebaldfawn, 2017)

A clinical study has been carried out at the University of Pittsburgh under the supervision of Edmund F. LoPresti, PhD. who aimed at self-awareness and social awareness of the people with ASD. 191 clients were tested, they were asked to create character representing their own preferences, personality and character. They played The Sims for 8 to 14 weeks. As the result 50 out of 57 clients reported better understanding of themselves after playing the game and 55/57 clients stated that the game was useful for experience of real-life processes and relationships. (F. LoPresti)

6.2. GAMES FOR CHILDREN WITH CEREBRAL PALSY

Cerebral palsy (CP) is developmental disorder which causes physical disability and affects about 17 million people around the world. A half a million people, mainly children at very young age diagnosed every year. Cerebral palsy is caused by a brain injury in the period of fetal development or birth. This disorder affects mainly muscle control and coordination, however it often coexists with other conditions such as epilepsy, cognitive disabilities etc. People affected by CP tend to have lower endurance, muscular strength, and cardiorespiratory fitness, compared to people without any disability. Just as in the case of autism, there is no cure, however, long-term consistent therapy can weaken the symptoms. (Gutierrez Cortes)

6.2.1.   ORBIT

Dr David Hobbs from Flinder University in Australia assembled a team and focused on hand functions and hand sensitivity of children with CP. They together developed the OrbIT gaming system, which focuses mainly on children with limited hand functions and tactile sensation. The system consists of two parts, a computer with all the software included and a spherical console which requires to be controlled by both hands but does not require fine motoric skills. People affected by CP tend to have one dominant hand, therefore the orb requires to be controlled by both hands, to make sure that even the weaker one gets the proper therapy, if the missing hand is detected the game would be paused. The controller also responds to the game activities by vibrating and providing player with tactile feedback. There are two basic modes, in the first one player navigates the squirrel to climb up a tree, gathering nuts and coins while avoiding branches, in the second one pilots a biplane and avoids windmills, barns, silos or other planes. (Hobbs, 2017)

The research team launched a trial testing, providing OrbIT for six weeks to several children with CP. The system has proved therapy for both people suffering of CP and people recovering from stroke. Team is planning to implement this device further to the treatment of Parkinson´s disease. In addition, the gaming with OrbIT encouraged further social communication among children and especially siblings where OrbIT became a shared passion, since the kids can both play the same game no matter the handicap. (FG Team, 2017) The team around Dr Hobbs is currently developing an i-boll witch works on

the same principle as ObrIT but it can be adapted to any other commercial games. (Smith, 2017)

6.2.2. NINTENDO WII

Nintendo Company developed a gaming console, which instead of joystick uses a controller that detects movement and action buttons. This way the Wii console requires movement of parts or whole human bodies. Different types of controllers like balance boards, a racing wheel, or a floor mat can be attached to the console. This variation of Nintendo console focuses primarily on the sport games such as swimming, archery, bowling, swordplay and many others. (The Editors of Encyclopaedia Britannica, 1998e) The Nintendo Wii variation the Nintendo Wii Fit has been created, which incorporates additional 70 activities including Yoga, strength exercises, aerobic, balance games, etc. It also consists of removable Fit Meter which can track running or hiking and synchronize them to personal data. This way the Nintendo is trying to encourage people to stay active and healthy in an entertaining way. ("Nintendo Wii Fit")

Despite being designed for general public a research had been carried out at the King Abdulaziz University in Saudi Arabia a research on interactive games like Nintendo Wii Fit and their effects on children with cerebral palsy. 40 children aged 6-10 years diagnosed with CP were divided into two groups. First group A played Nintendo Wii Fit for 12 weeks, 20 minutes a day, while the other control group B did not play at all. The children were tested by 7 tasks, which should check their movement assessment, manual dexterity, aiming and catching skill, balance exercise, one of the Bruininks-Oseretsky Test of Motor Proficiency exercises, where children were asked to touch a swinging ball and therefore test their upper-limb body coordination and finally their endurance in 1-minute walking test. As the table below suggests, there is a big improvement in all areas of testing in the first group, while the results of the control group were without any significant changes. The biggest improvement was noted at the area of endurance, where children were able to walk longer time than before testing and at the area of manual dexterity. (AlSaif & Alsenany, 2015)

Tab.6.2.2.-1. Comparison of playing group and control group of children diagnosed with CP

(unit: Log(Result))

Task	Group A		Group B	
	Pre	Post	Pre	Post
Movement assessment	38.3 ± 5.42	44.1 ± 5.21	38.9 ± 5.27	39.1 ± 5.16
Manual dexterity	10.4 ± 2.32	17.3 ± 1.25	11.1 ± 2.44	11.3 ± 2.42
Aiming and catching	12.5 ± 2.91	15.9 ± 3.18	12.8 ± 3.15	13.1 ± 3.11
Balance	12.1 ± 3.12	16.1 ± 3.10	12.5 ± 3.62	12.7 ± 3.74
Bruininks-Oseretsky Test of Motor Proficiency	2.23 ± 0.47	3.78 ± 0.39	2.82 ± 0.51	3.12 ± 0.66
1-minute walk	90.01 ± 7.21	98.8 ± 6.75	91.1 ± 6.93	91.8 ± 6.82

(data extracted from AlSaif & Alsenany report)

In different study *Active Video Games and Children With Cerebral Palsy: the Future of Rehabilitation?* which was presented at the International Conference on Virtual Rehabilitation on June 27 – 29 in 2011 in Zurich, Switzerland the authors believe that Nintendo Wii Fit provides a number of repetitive task, which can be done in safe environment, have real-time feedback and be encouraging enough to be suitable for proper rehabilitation. From the set of offered games, four were selected – skiing, snowboarding for their positioning of pressure and centroid, while biking and jogging for their energy demandingness. Eleven children diagnosed with CP were participating by playing each game in random order for 10 minutes with 5 minutes rest between them. As the result, the jogging appeared as the best choice for enhancing cardiorespiratory fitness, while snowboarding is the most suitable for centroid displacement. The study proved the possible implementation of the interactive games as a promising approach to

the rehabilitation of motor functions and aerobic capacity for people affected by CP. (Ballaz, Robert, Lemay, Ballaz, & Robert, 2011)

7. FUTURE APPLICATIONS

7.1.1. DIGITAL TWIN

The idea behind the concept of Digital Twin is to create through virtual reality and augmented intelligence an accurate representation of some object, electronic device or even human avatar. Although in medicine it is yet an implementation of future. The 3D model is given all the qualities of physical object. Digital representation inherits all the attributes of original subject. It is designed as a virtual image of the patient´s health status. The human model is precisely generated by the detailed data of given patient, composed of the most basal information like height, gender, weight, and more complex ones such as heart rate, or CT scan. This biomedical visualisation is modelled from the whole health record of a patient, thus it behaves and looks exactly as the patient´s body. In case of disease, physicians can use the model to simulate symptoms, possible ways of treatment and decide for the best option according to the given computer results. Data can be modified any time and the visualization will show the real-time reaction, for example during some unexpected event while undertaking the surgery. It can be also used as a preventive tool to make sure that patient is given proper treatment at the right time. (Philips, 2018) The data can also be stored at cloud storages therefore available any time at patient´s smartphone, where is possible to check immediate health status before even contacting their practitioner.

However, the project of Digital Medicine is still in very early stage of development. Its potential for the future of medicine might be enormous. It may completely change the medicine and health management, physicians will be able to react in advance to any consequence, which would have remained unforeseen. Also, the multinational consultation would be possible with experts worldwide. On the other hand, there is a danger of leakage of personal health records as well as stealing of private data as those information would be available online. (Topol, 2016)

CONCLUSION

Games can be regarded as a waste of time, causing negative aspects on children. Even though, it is possible to argue that the time spent playing must be regulated and precautions must be taken in order to not become an addiction. In my bachelor thesis I have tried to prove that games are able to provide humanity with rather positive aspects. Not only computer games, but video games in general, no matter if serious or conventional ones do have a purpose in medical conditions. As has been illustrated in the thesis games can be used in whole variety of causes considering healthcare and medical training.

Apart from being entertaining, games have provably vast educational value for medical students, physicians and even patients. Number of games focuses on medical education and even more of them is used in healthcare therapy. In medical training they are designed to further students´ knowledge of anatomy, microbiology and other fields, but also to provide simulation for surgeons to improve their skills and gain additional knowledge. On the other hand, considering the healthcare the games proved themselves to have great potential in the way of rehabilitation for children diagnosed with ASD or CP, pain reduction, or as a way of treatment after-brain injury. We can certainly expect more utilisation of this kind of video games to appear in the future because of increasing level of technology and visualisation possibilities.

Virtual reality is about to develop further in the future, its implementation in gaming is more and more frequent. 3D modulations and visualisation enhancement allowed players to feel present in the game. The VR in the field of medical training has probably the biggest potential for the future implementation. Virtual reality already serves to many medical experts, students, and patients. It allows us to discover human body ourselves, makes possible the training which would be otherwise possible only at dissecting rooms at home or specialised laboratories, it is not necessary to use real bodies anymore. It allows trainees to perform multiple tasks repeatedly and on their own, which would not be possible during the lectures. Virtual reality helps already physicians in the field of laparoscopy, neurosurgery, acupuncture training and many others. In addition, VR is powerful tool considering the pain reduction, since patients do not focus on the painful

impulse and pain itself becomes more tolerable. Phobia therapy uses virtual reality as a place where patients can encounter their fear and tackle with their phobias.

Considering the augmented intelligence, it is designed to enhance human ability to learn, gather and organize information. The main potential can be used in healthcare, although, this kind of utilization is about to develop mainly in the future. Augmented reality can be used for comparing data of patients, creating virtual images of body parts designed according personal data. The advantage is that AR is able to react real-time and to modify visualizations.

During the writing of this thesis and searching for new information I have encountered many interesting facts which I have never heard of before. Gaming plays important part in everyday life not only within the young generation and serious games developed with purpose to make our lives easier, make the treatment and rehabilitation more effective and joyful. I really enjoyed the process of learning new aspects of videogames industry, I was greatly surprised by the amount of possible usage of gaming technology, and by the positive aspects brought into the field of medical training. Unfortunately, it was impossible to mention all of them, therefore I tried to mention the most interesting ones. There are many other fields where computer games may play important part, not only medicine but also education, building industry, elite sport and many others.

REFERENCES

Arnab, Sylvester, I. Dunwell, K. Debattista. "Serious Games for Healthcare: Applications and Implications"

Bauman, Eric B. "Game-Based Teaching and Simulation in Nursing and Health Care"Essential Facts About the Computer and Video Game Industry [Online]. (2018).

Retrieved November 05, 2018, from http://www.theesa.com/wp-content/uploads/2018/05/EF2018_FINAL.pdf

Video Gaming Industry Overview [Online]. (2018). Retrieved November 06, 2018, from https://www.wepc.com/news/video-game-statistics/

Hymas, C., & Dodds, L. (2018). Addictive video games may change children's brains in the same way as drugs and alcohol, study reveals [Online]. *The Teegraph*, 1. Retrieved from https://www.telegraph.co.uk/news/2018/06/12/addictive-video-games-may-change-childrens-brains-way-drugs/

Reader's digest. The Pros and Cons of Playing Computer Video Games [Online]. Retrieved October 29, 2018, from http://www.readersdigest.com.au/healthsmart/conditions/mental-health/pros-and-cons-playing-computer-video-games

Miller, L. (2018). Games for Health: Exploring How Video Games Can Improve Health and Health Care [Online]. *Brain World*, 1. Retrieved October 30, 2018 from https://brainworldmagazine.com/games-health-exploring-video-games-can-improve-health-health-care/

Tao, L. Microbe Invader [Online]. Retrieved October 31, 2018, from http://www.microbeinvader.com/about/

Tao, L., a, Microbe Invader: Teaching microbiology through a computer role playing game [Online]. Retrieved November 1, 2018 from http://ieposter.com/eposter/377/microbe-invader-teaching-microbiology-through-a-computer-role-playing-game.html

Zettl, R. (2014), Facebook feedback [Online]. *Facebook*. Retrieved November 14, 2018 from https://www.facebook.com/pg/MicrobeInvader/community/?ref=page_internal

Quach, C.J. (2013) Facebook feedback [Online]. *Facebook*. Retrieved November 14, 2018 from https://www.facebook.com/pg/MicrobeInvader/community/?ref=page_internal

Medical Joyworks LLC. (2010). Prognosis: Your Diagnosis [Online]. Retrieved November 02, 2018, from https://itunes.apple.com/us/app/prognosis-your-diagnosis/id392489854?mt=8

Medical Joyworks. (2010). Prognosis: Cases [Online]. Retrieved November 02, 2018, from http://www.prognosisapp.com/cases/

Lupe, Vera (2012) Amazon feedback [Online]. *Amazon*. Retrieved November 15, 2018 from https://www.amazon.com/product-reviews/B004PDBCT6/ref=acr_dpappstore_text?ie=UTF8&showViewpoints=1

Mohan, D., Schell, J., & Angus, D. C. (2016). Not Thinking Clearly? Play a Game, Seriously! [Online]. *Jama*, 316(18). https://doi.org/10.1001/jama.2016.14174

Night Shift [Online]. Retrieved November 12, 2018, from https://www.schellgames.com/games/night-shift

 Kotaku. (2018). Night Shift: More Than Just a Video Game [Online]. *YouTube*. Retrieved Nvember 11, 2018, from https://www.youtube.com/watch?v=wif_Xe6pEFg

Kahneman, D. (2012). Myšlení: rychlé a pomalé. V Brně: Jan Melvil.

Mohan, D., Farris, C., Fischhoff, B., Rosengart, M. R., Angus, D. C., Yealy, D. M., et al. Efficacy of educational video game versus traditional educational apps at improving physician decision making in trauma triage: randomized controlled trial [Online]. *Bmj*, 12. https://doi.org/10.1136/bmj.j5416

Virtual Reality Society. What is Virtual Reality? [Online]. *Virtual Reality Society*, 1. Retrieved November 19, 2018, from https://www.vrs.org.uk/virtual-reality/what-is-virtual-reality.html

BioDigital Inc. (2011). BioDigital [Online]. Retrieved November 19, 2018, from https://www.biodigital.com/product

BioDigital Inc. (2011a). BioDigital Human 2019 [Online]. Retrieved November 20, 2018, from https://itunes.apple.com/us/app/biodigital-3d-human-anatomy/id771825569?mt=8

BioDigital [Online]. *Revolvy*. Retrieved November 21, 2018, from https://www.revolvy.com/page/BioDigital

myFace. (2017). Eperience CIVA, the Craniofacial Interactive Virtual Assistant [Online]. Retrieved November 22, 2018, from https://www.myface.org/civa/

The Editors of Encyclopaedia Britannica. (1998). Laparoscopy [Online]. *Encyclopedia Britannica*. Retrieved November 27, 2018, from https://www.britannica.com/science/laparoscopy

LAPARO Medical Simulators [Online]. (2016). Retrieved November 27, 2018, from https://laparo.pl/en/

Changchien, E., Tawfik, D., & Kukreja, S. Short-term use of a Laparoscopic Virtual Reality Simulator in One Surgical Residency Program: A Survey of Residents [Online]. *Sages*. Retrieved November 28, 2018, from https://www.sages.org/meetings/annual-meeting/abstracts-archive/short-term-use-of-a-laparoscopic-virtual-reality-simulator-in-one-surgical-residency-program-a-survey-of-residents/

Paquette, J., Lemyre, M., Vachon-Marceau, C., Bujold, E., & Maheux-Lacroix, S. (2017). Virtual Laparoscopy Simulation: a Promising Pedagogic Tool in Gynecology [Online]. *Jsls: Journal Of The Society Of Laparoendoscopic Surgeons*, 21(3). https://doi.org/10.4293/JSLS.2017.00048

Open Simulation [Online]. (2016). Retrieved November 28, 2018, from http://opensimulation.org/

Dickson, B. (2017). What is the difference between artificial and augmented intelligence? [Online]. *Techtalks*. Retrieved November 23, 2018 from https://bdtechtalks.com/2017/12/04/what-is-the-difference-between-ai-and-augmented-intelligence/

The Editors of Encyclopaedia Britannica. (1998a). Acupuncture [Online]. *Encyclopedia Britannica*. Retrieved November 25, 2018, from https://www.britannica.com/science/acupuncture

Augmented Intelligence. (2018). Acupuncture VR training in Beijing China [Online]. *YouTube*. Retrieved November 28, 2018, from https://www.youtube.com/watch?time_continue=108&v=gRQ1bLqvxqE

Yau, E. (2018). Virtual reality helps Chinese medicine students learn acupuncture and doctors treat cancer [Online]. *South China Morning Post*. Retrieved November 25, 2018, from https://www.scmp.com/lifestyle/health-wellness/article/2169092/virtual-reality-helps-chinese-medicine-students-learn?fbclid=IwAR1F3hzIxDwO9yWHMhnO-5H3UFPuTnfsWyQo-ohw3hqfnWcQrpVN-PEvRA

Newman, T. (2017). All about the central nervous system [Online]. *Medical News Today*. Retrieved April 24, 2019, from https://www.medicalnewstoday.com/articles/307076.php

Stasio, N. 5 Games to Help with Brain Injury Recovery [Online]. *Lotsa Helping Hands*. Retrieved April 28, 2019, from https://lotsahelpinghands.com/blog/brain-injury-recovery/

Lumos Labs, Inc. Luminosity [Online]. Retrieved May 1, 2019, from https://www.lumosity.com/en/

Hardy, J. L., Nelson, R. A., Thomason, M. E., Sternberg, D. A., Katovich, K., Farzin, F., et al. (2015). Enhancing Cognitive Abilities with Comprehensive Training: A Large, Online, Randomized, Active-Controlled Trial [Online]. *Plos One*, *10*(9). https://doi.org/10.1371/journal.pone.0134467

MyTherappy [Online]. Retrieved May 3, 2019, from https://www.my-therappy.co.uk/information/terms

The Editors of Encyclopaedia Britannica. (1998b). Protein [Online]. *Encyclopedia Britannica*. Retrieved February 2, 2019, from https://www.britannica.com/science/protein

FoldIt: Solve Puzzle for Science [Online]. Retrieved February 7, 2019, from https://fold.it/portal/

J. Coren, M. (2011). Foldit Gamers Solve Riddle of HIV Enzyme within 3 Weeks [Online]. *Scientific American*. Retrieved February 9, 2019, from https://www.scientificamerican.com/article/foldit-gamers-solve-riddle/?redirect=1

Armstrong Moore, E. (2011). Foldit game leads to AIDS research breakthrough [Online]. *Cnet*. Retrieved February 9, 2019, from https://www.cnet.com/news/foldit-game-leads-to-aids-research-breakthrough/

The Editors of Encyclopaedia Britannica. (1998c). Pain [Online]. *Encyclopedia Britannica*. Retrieved October 25, 2018, from https://www.britannica.com/science/pain

Gramza, J.Eagan, J. (Ed.). (2008). Soldiers Get Virtual Reality Therapy for Burn Pain [Online]. *Sciencentral*. Retrieved October 27, 2018, from https://www.youtube.com/watch?v=jNIqyyypojg

VRpain [Online]. Retrieved October 25, 2018, from http://www.vrpain.com/

The Editors of Encyclopaedia Britannica. (1998d). Autism [Online]. *Encyclopedia Britannica*. Retrieved May 5, 2019, from https://www.britannica.com/science/autism

Autism Speaks Inc. Autism Facts and Figures [Online]. *Autism Speaks*. Retrieved May 4, 2019, from https://www.autismspeaks.org/autism-facts-and-figures

FaceSay: Social Skills Software Games [Online]. Retrieved May 4, 2019, from http://www.facesay.com/

Rice, L. M., Wall, C. A., Fogel, A., & Shic, F. (2015). Computer-Assisted Face Processing Instruction Improves Emotion Recognition, Mentalizing, and Social Skills in Students

with ASD [Online]. *Journal Of Autism And Developmental Disorders*, 45(7), 2176-2186. https://doi.org/10.1007/s10803-015-2380-2

Let´s Face It [Online]. Retrieved May 5, 2019, from http://web.uvic.ca/~letsface/letsfaceit/

Wright, J. (2014). Pac-Man maze leads children with autism to 'good' smiles [Online]. *Spectrum*. Retrieved May 5, 2019, from https://www.spectrumnews.org/opinion/pac-man-maze-leads-children-with-autism-to-good-smiles/

piebaldfawn. (2017). Autism Spectrum Disorder Trait v1.1 [Online]. *Mod The Sims*. Retrieved May 7, 2019, from http://modthesims.info/d/604824/autism-spectrum-disorder-trait-v1-1-cats-and-dogs-compatible.html

F. LoPresti, E. Therapeutic Use of Life Simulation Games for People with Cognitive Impairments [Online]. Retrieved May 7, 2019, from https://www.herl.pitt.edu/symposia/virtual-reality/presentations/LoPresti.pdf

Gutierrez Cortes, N. Cerebral Palsy – What is Cerebral Palsy? [Online]. *Cerebral Palsy Group*. Retrieved May 6, 2019, from https://cerebralpalsygroup.com/cerebral-palsy/

Hobbs, D. (2017). Game therapy: serious video games can help children with cerebral palsy [Online]. *The Conversation: Academic Rigour, Journalistic Flair*. Retrieved May 6, 2019, from https://theconversation.com/game-therapy-serious-video-games-can-help-children-with-cerebral-palsy-72950

FG Team. (2017). OrbIT Gaming Platform Introduces Interactive Games to People with Limited Hand Function [Online]. *Fitness Gaming*. Retrieved May 6, 2019, from https://www.fitness-gaming.com/news/health-and-rehab/orbit-gaming-platform-introduces-interactive-games-to-people-with-limited-hand-function.html

Smith, M. (2017). SA gaming technology OrbIT i-boll could help millions worldwide [Online]. *The Advertiser*. Retrieved May 6, 2019, from https://www.adelaidenow.com.au/business/sa-business-journal/sa-gaming-technology-orbit-iboll-could-help-millions-worldwide/news-story/cc3e966fc294a86e44b21fcf68a56f1e

The Editors of Encyclopaedia Britannica. (1998e). Nintendo Wii [Online]. *Encyclopedia Britannica*. Retrieved May 8, 2019, from https://www.britannica.com/science/Nintendo-Wii

Nintendo Wii Fit [Online]. Retrieved May 8, 2019, from https://www.nintendo.com/games/detail/wii-fit-u-bundle-wii-u/#game-info

AlSaif, A. A., & Alsenany, S. (2015). Effects of interactive games on motor performance in children with spastic cerebral palsy [Online]. *Journal Of Physical Therapy Science*, *27*(6), 2001-2003. https://doi.org/10.1589/jpts.27.2001

Ballaz, Robert, M., Lemay, M., Ballaz, L., & Robert, M. (2011). [Online]. *2011 International Conference On Virtual Rehabilitation*. https://doi.org/10.1109/ICVR.2011.5971808

Philips. (2018). Philips Digital Twin concept [Online]. Retrieved November 27, 2018, from https://www.youtube.com/watch?v=H6JzPCbyVSM

Topol, E. (2016). Digital medicine: empowering both patients and clinicians [Online]. *The Lancet*, *388*(10046), 740-741. https://doi.org/10.1016/S0140-6736(16)31355-1

LIST OF ABBREVIATIONS

ABBREVIATION	EXPLANATION
3D	three-dimensional
AI	artificial intelligence
AIDS	acquired immunodeficiency syndrome
AR	augmented reality/ augmented intelligence
ASD	autism spectral disorder
Dr.	doctor
CP	cerebral palsy
CT	computerized tomography
HIV	human immunodeficiency virus
ETC.	et cetera
IOS	operational system developed by Apple Inc.
INC.	incorporation
MS2	second-year medical student
NBME	National Board of Medical Examiners
PhD.	doctor of Philosophy
USA	the United States of America
VR	virtual reality

LIST OF TABLES

LIST OF FIGURES