Usability of i4Ski

A prototype exergame in the field of prevention and health promotion

Master Thesis

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Declaration

I declare that I have developed and written the enclosed Master Thesis completely by myself, and have not used sources or means without declaration in the text. Any thoughts from others or literal quotations are clearly marked. This work was not used in the same or in a similar version to achieve an academic grading or is being published elsewhere.

Krems, 30.06.2017 ....

Signature

Abstract

The main purpose of this study was to evaluate the usability of a prototype skiing exergame in the field of prevention and health promotion. In addition, an expert evaluation with the intention to detect weaknesses of the system has been implemented.

Digital technologies, either entirely new or additions to existing procedures are becoming standards in healthcare. Generally, standardized assessments like usability evaluations are key parts to maintain and improve standards in daily clinical practice. The field of prevention and health promotion is lacking quantifiable evidence of beneficial effects on individual physical health. To counter this problem in general, and specifically, to adjust an adequate hip-knee-ankle axis (HKA) with Microsoft Kinect II, an existing skiing exergame has been co-developed within the cooperation of a student of media technology.

The main research question was: “What is the grade of usability of the prototype exergame?” The methodology of this study is a quantitative mixed method approach. A questionnaire has been designed to query usability of the prototype exergame according to the System Usability Scale (SUS) and to receive an expert evaluation. This questionnaire has been conducted with ten defined motion experts, practicing physiotherapists and sport scientists, who tested the game and rated the system.

The result of the usability rating is a SUS score of 81.3, which classifies the prototype exergame as acceptable/good value. The expert evaluation shows a differentiated view. The evaluators were consent with statements regarding an adequate HKA detection, but not clearly consent with HKA error notifications. No clear recommendation for the prototype exergame can be given, although there is a slight consent with these statements. After redevelopment and implementation of received expert feedback, the system may have the potential to be implemented to standard health care.

Kurzfassung

Das Hauptziel dieser Arbeit war die Evaluierung der Gebrauchstauglichkeit eines prototypischen Ski-Exergames im Bereich der Prävention und Gesundheitsförderung. Um zudem Schwächen dieses Systems aufzudecken, wurde zusätzlich eine Expertenevaluierung durchgeführt.

Der Einsatz digitaler Technologien ist ein fixer Bestandteil im Gesundheitswesen. Aus diesem Grund nehmen standardisierte Bewertungen wie Evaluationen der Gebrauchstauglichkeit Schlüsselrollen in der Sicherstellung von Standards im klinischen Alltag ein. Da mangelnde Evidenz in den Bereichen Prävention und Gesundheitsförderung, als auch bei Anpassung einer adequaten Beinachsenerkennung mittels der Microsoft Kinect II, wurde eine Kooperation etabliert, um entsprechenden Nachweis zu erbringen.

Die hauptsächliche Fragestellung lautet: Wie hoch ist der Grad der Gebrauchstauglichkeit des entwickelten Prototyps? Die zugrundeliegende Methodik bediente sich einem Methoden-Mix. Dieser quantitative Forschungsansatz wurde mittels Fragebogen umgesetzt, welcher einerseits den System Usability Score (SUS) abfrägt, andererseits wurde eine Expertenevaluation durch eigens erstellte Aussagen zum Einsatz gebracht. Die Teilnehmergruppe bestand aus zehn definierten Bewegungsexperten, in diesem Fall praktizierende PhysiotherapeutInnen und SportwissenschafterInnen.

Das Ergebnis weist einen SUS-Wert von 81.3 auf, was im Vergleich zu bestehender Evidenz als akzeptabler und guter Wert klassifiziert werden kann. Die Auswertungen der ExpertInnenevaluation stellen ein differenziertes Bild dar. Die TeilnehmerInnen zeigten Zustimmung bei Aussagen bezüglich einer adequaten Beinachsenerkennung, jedoch keine klare Zustimmung bezüglich der richtigen Anzeige eines jeweiligen Fehlers. Es kann daher keine eideutige Weiterempfehlung interpretiert werden, obwohl eine leichte Zustimmung zu entsprechender Aussage besteht. Nach Weiterentwicklung und Umsetzen des erhaltenen Expertenfeedbacks, hat das System das Potential in die Regelversorgung aufgenommen zu werden.

Table of Content

1 Introduction

Digitization and digital technologies are more and more entering the health care system. They have the potential not just to support the existing system, but to improve and rather revolutionize it. This phenomenon is not limited to the health care sector, but to nearly every part of our lives [1], [2].

The Austrian government tries to overcome this issue inter alia with the national HTA[1] strategy. This tool systematically rates technologies in healthcare. The main objective is to evaluate, if innovative technologies can be utilized in the standard care. The interest of patients is paramount, as well as securing and quality improvement of the healthcare system [3].

Today, there are millions of mobile health apps available. [4] For one thing, this sounds positive, because of potential health benefits of users. Then again, the content and function of these applications can barely be proven about customer safety, usability, outcome and sustainability. Here it is to the HTA institutions to prove relevant software, that aims to get into the standard care.

The success and popularity of many applications lies in the fact that gamification is implemented. This strategy uses extrinsic feedback to motivate the user to achieve the respective applications' objective. Applications that use the Mircosoft Kinect as hardware component are better and better investigated meanwhile. But the evidence in various fields of applications is still not sufficient. The present study has the objective to gain more insights in this field. An extensive insight into this issue is given in chapter 2.1.3 and 2.4.

Analysing the longitudinal axis of the lower extrimity is a key element in the treatment and prevention of knee malpositions and complaints. Beside many other factors that influence the health and correct load of the knee joint, this kind of analysis is well investigated and vaild method to prevent subjects from pain and dysfunction of the joints of the lower extremity and/or treat any kind of them.

[1] Health Technology Assessment

To come back to the healthcare system, there are diversified reasons to develop and evaluate new technologies in the healthcare system and the field of secondary prevention. Generally, there is the factor of rapidly increasing costs in the healthcare sector, which leads to steadily rising expenses for the general public [5]. In particular, the last view years (2009-2016) the pubic authority had to cover the debts of the public Austrian insurance companies, because they did not get rid of the annually increasing costs of the healthcare system and were not able to realise reforms. In 2017, so the so called ‚Gebarungsvorschau‘ from ‚Der Rechnungshof‘ again predicts extensive divestures [6].

Working together is a key element as a physiotherapist. If the communication between therapist and client is not at an appropriate level, where good communication and confidence is required, therapy interventions can be bootless. The intervention itself does only make up 15 % of the therapy success, compliance of the patient reaches up to 40 %, and the therapist-patient relationship makes up 30 % of the efficacy of the intervention [7].

As the degree progamme Digital Healthcare is built on multidisciplinarity and the facts given above about therapy efficacy, it seemed likely to work together with experts in the field of digital media. The algorithm and software basis, which is used for this work, comes from a student of digital media of FH St. Pölten. Together a prototype ski exergame, which recognizes and corrects the mechanical axes of the lower extremity has been developed. This process is described detailed in chapter 4.

Expert evaluation and feedback about the usability is important, when creating prototype software in the use in medical background.

Pählmann et al (2016) state that: “Creative approaches to healthcare are needed to cope with ageing populations and increasing economic pressure. Commercially available gaming systems, which provide advanced technology made available for the mass market at low cost, have thus received growing interest. Systems such as Microsoft Kinect are significantly less expensive than most medical sensing devices, but have the potential to provide accuracy sufficient for clinical practice.” [8]

As this study refers to an exergame that contains a ski run, facts and issues of this sport and consequences for the healthcare are discussed. The most common ski related injuries occur on the knee joint and rose about 30 % in the last past 30 years. The most common injury is the tear of the medial collateral ligament, followed by anterior cruciate ligament tears.

Injury prevention on the slopes can be handled with effective skiing techniqes like: correct weight bearing, parallel legs, equally bended hip, knee and ankle joints. Before skiing, simple exercises like single- and double leg squats with a special focus on the knee positions, side steps and balance training can prepare the upper extremity to prevent injuries. [9]

Why skiing? Skiing in Austria has a long tradition and was originally brought to the alpine region from Norway in 1870. In the late 19th century first skiing clubs has been established in Vienna and Lower Austria. In the following years, technical development took place with substantial influence of Austira [10]. Nowadays, skiing has become a mass sport in Austria. The average Austrian absolvates more than 51 skier-days a year, the 3rd highest rate worldwide behind France and USA. 34 % of the Austrian population is skiing or snowboarding, which is the highest ratio in the world [11] [12] [13].

To come back to the digital transformation of our society, a deeper insight into background is given. Digitisation and 4.0 are indispensable terms in medicine. Characteristically, the degree course Digital Healthcare is named after this interface. The so called 4th industrial revolution ties seemlessly on the still ongoing automisation of production. The increasing digitisation of physical things and cyberspace is gaining in importance. So-called cyber-physical systems (CPS) describe the fusion of physical applications and the cyberspace. These smart systems are connecting to each other and exchange data. These processes run automatically, so that humans do not have to intervene. The term Internet of Things (IoT) describes the networking of digital subjects through their embedded systems with the internet. While the CPS forms the superordinate structure, the IoT underlies as its execution technology [14, pp. 15–18].

Although technical progress sounds promising considering the steadily increasing costs of the healthcare system, the main intention must be the healthcare provision of each citizen and its improvement. The aim of technology in the healthcare sector should always be an added value to the population, not to rationalize and replace humans in the care and treatment. A simple reason for this position is the fact, that humans need other humans. They live from interaction and social integrity. Investigations showed, that treatment alone is not enough to become and stay healthy. There is also a need of human attention, response and gesture [15].

2 Theoretical Background

Delivering valuable and intelligible to all state-of-the-art background information, which is important for the understanding of the presented issues, is the intention of this chapter. At first, an extensive insight into existing healthcare systems and current progress is given. After this, terms and definitions in the field of public health and health promotion are provided. The second part of the chapter theoretical background delivers a short introduction to the medical background, especially explanations about the function and biomechanics of the mechanical axis of the lower extremity. The final part of this chapter covers obligate information about the utilized technology in this paper and the current state of research in this field.

2.1 Healthcare

Most of the common lifestyle diseases can be partly lead back to changed lifestyle habits and behaviour [16, p. 37]. A combination of smoking, alcohol abuse, too little exercise, overconsumption of simple carbohydrates, fructose in the form of fruit juice and to little fibres in the modern diet lead to the so-called metabolic syndrome[2], that reduces life years and increase the costs of the public healthcare significantly [18, pp. 125–190]. Besides genetic, epigenetic and environmental factors, also life-style and metabolism play an important role in human longevity [19]. Additionally, the QoL[3] is an essential part in these considerations. It can be measured through various methods and is defined as the ability in participating in social interactions and individually valued activities of daily living [20]. Improvements of QoL are not just relevant in older people, but in those who suffer from metabolic diseases or already show risk factors for it, for example severe obesity. Here, physical activity can significantly improve QoL already after a six week intervention [21].

[2] Metabolic syndrome is collective term for a group of five risk factors, that cause strokes, diabetes, heart diseases, cancer and dementia. These factors are: obesity, high triglyceride level, low HDL level, high blood pressure, high fasting blood sugar [17].

[3] Quality of Life

The importance and urgency of the above-mentioned issues lies in the fact of an aging population worldwide. This aged population will need appropriate medical services including care and treatment after loosing fully or partly physical and/or mental health [22]. People in the age of 60 or above will increase from 23 % in 2014 to 34 % in 2050 in Europe, which will now and then represent the oldest population worldwide. The UN suggests an adoption of the healthcare system, including new ways of treatments and prevention to satisfy the needs of an older population. Especially the prevention of diseases with the support of technological progress is a chance to decrease healtcare expenditures and to improve the QoL [23].

This democratic change in Western civilisation appears like a threat for the health system and the welfare state. The older humans get the more medical treatment and equally monetary resources are required to fill ones basic (medical) needs. There is a realistic risk, that optimal medical supply cannot be satisfied and financed anymore in future. This could lead to (more) social imbalance and in former case to political instability [24, pp. 1, 46].

A possible breakthrough is already seen in the effective implementation of prevention as meaningful part in healthcare to reduce costs. Furthermore, the broadly use of technical solutions, for example in sick-nursing, geriatric care, sports injury prevention, rehabilitation or in prevention of lifestyle diseases and many more, are part of this idea. Mostly, there are two kind of typically concerns about (new) technologies and their use in practice: an immatureness of developed hard- or software and secondly an insufficient usability in everyday life. Here it is to us, to find solutions that are compatible to high-end technical devices and partly complicated handling that only experts understand. Kinect-based systems are one of these mentioned technologies that have already been investigated in the clinical routine [25], [26], [27].

Considering the facts above and looking at the actual use of these technologies, there is a gap. One possible concern may be the few investigated technology acceptance in this field. Clinicians use to act sceptical to new technologies in their working environment. Possible negative assumptions may be: fear of getting replaced by technique, technical systems don´t work stable or safe enough for patients, technical solutions are badly operable in clinical routine, and many more.

In Austria, the stroke[4] is one of the leading causes for disability, cognitive impairment and death. In the year 2015, about 0,8% of the total population in Austria sufferd from the consequences of stroke. Beyond the age of 60 years, the risk of suffering from a stroke more than doubles for each successive decade of life [29]. Therefore, the costs are expected to rise for an aging population. There is evidence, that virtual rehabilitation shows great promise in stroke rehabilitation to improve the patients´ outcome [25], [26], [30].

Virtual rehabilitation systems have grown in appeal to orthopaedic surgery. Injuries concerning the musculoskeletal system are common medical indications for a surgery. In Austria, 107.441 people already underwent a knee- or hip surgery [31]. Relying to an aging population, this number is predicted to increase in the next decades. Following surgery, rehabilitation is a critical component for resuming physical function and normal activities of daily living. Studies support the usage of Kinect-based rehabilitation systems as an alternative method to achieve improvements in functional variables [32], [33].

2.1.1 Healthcare international

Healthcare systems in the world differ significantly as there are enormous economic differences in the countries and their welfare. As the expenditures of healthcare systems are mostly drawn by the state and its organisations [34], there is a high correlation in health expenditures and GDP of a national economy [35]. The ultimate responsibility for a country´s healthcare system lies with the government. The most part of health care is provided by the public sectors, but there are also private and informal sectors that provide health care [36].

Contemplating the progress of healthcare in developing countries, a decrease of infectious diseases and diet-related illnesses of 20 % resulted from 1990 and 2001. But in the same time, chronic degenerative diseases are increasing rapidly. In 2030, the most common diseases will be endogenous depressions, ischemic heart diseases and cerebrovascular diseases. The western lifestyle causes an increase of above mentioned chronic uninfectious diseases. But, as a consequence of an expected worldwide economic improvement, the burden of disease is expected to decrease [37, p. 8].

[4] A stroke is an accident in cerebrovascular arteries, which causes an undersupply of oxygen-rich blood to brain tissue. This leads to a dying of brain cells within a few minutes. Depending on the affected brain area, symptoms like paralysis in various body parts, speech or visual problems occur [28]

2.1.2 Healthcare Austria

The spendings in the Austrian healthcare are annually rising. Although the costs for prevention rise more rapidly than the all-over spendings do, it is still a very small matter of expense with 2,09 % of the public health spendings and 1,58 % of the all-over spendings in the Austrian healthcare sector in 2015 (Fig. 1) [38].

Überblick - Gesundheitsausgaben in Österreich laut System of Health Accounts (SHA) [1] 1990 - 2015, in Mio. Euro								
Öffentliche und Private Gesundheitsausgaben [2]	1990	2000	2010	2011	2012	2013	2014	2015
Staat inkl. Sozialversicherungsträger	**7.896**	**14.850**	**22.685**	**23.250**	**24.391**	**24.766**	**25.655**	**26.513**
Stationäre Gesundheitsversorgung [3]	3.642	6.459	10.476	10.727	11.309	11.335	11.816	12.172
Ambulante Gesundheitsversorgung	2.141	3.813	5.533	5.682	5.946	6.167	6.386	6.642
Häusliche Pflege [4]	895	1.450	2.210	2.248	2.372	2.394	2.344	2.357
Krankentransport und Rettungsdienste	115	214	296	310	340	346	356	363
Pharmazeutische Erzeugnisse und medizinische Ge- und Verbrauchsgüter	775	2.133	3.084	3.195	3.276	3.325	3.509	3.672
Prävention	117	257	448	448	461	491	522	555
Verwaltung der Gesundheitsversorgung: Staat inkl. Sozialversicherungsträger	211	524	637	641	686	708	722	752

Figure 1: Health expenditures in Austria, 2015. [38]

Although the GDP[5] of Austria is increasing since 2013 and will have an estimated growth of 2,0 % in 2017 [39], the costs for the national health sector are growing faster than the GDP. In 2000, the percentage of health expenditure in relation to the GDP was 9,2 % and rose to its peak at estimated 10,4 % in 2015. This is the 10th highest rate in the world [40].

Within the health objectives and target control of the Austrian healthcare system, substantial key points of a reorientation of health policy have been dertermined. The “target control health” is seen as crucial means to strengthen health promotion and prevention [41].

2.1.3 Technology in healthcare

Technology and society interact in a continuous coproduction. The main question is not about how technical development takes place, but how the society promotes or inhibits these developments. Some theories of science fiction or conservative technology philosophies let us think that technology obtains independency without the control of the society. The opposite is the case, the needed structures for technical innovation, development and its distribution are already existent and society decides about the technology´s acceptance [42, pp. 185–191].

The need of technology and digital media in healthcare shows in the existence of various study programmes like Digital Healthcare. The aim of this programme is a targeted support of healthcare processes by media technologies.

[5] Gross domestic product

Interdisciplinarity multiplies the potential of possible solutions in different parts of healthcare systems [43].

In contrast to the example above in Austria, there is also a worldwide request in improvement of safety and quality of healthcare technology systems. Research papers point out, that frustrated health employees, time wasting and increasing harm to patients occur from under-designed or badly implemented health technologies. Useful implemented digital technology can lead to an improvement of healthcare performance as an addition and extension of existing healthcare services, instead of replacing or degrading health professionals [44].

In the field of health promotion and digital technologies, more evidence is needed. Investigators suggest “interventions with participatory and user-generated features”. Differences in the health provision could be worked out regarding the reachability of vulnerable populations [45].

A meaningful use of new technologies also depends on the technology acceptance of the developed product. The TAM[6] of Davis (1989) predicts the user´s acceptance based on two factors. The PU[7] and PEOU[8] give an insight of the user´s probability to use the technology [46].

Investigations of the TAM with a telehealth sytem on elderly people showed positive perceptions of PU and PEOU [22]. Considering the facts in Chapter 2.1. Healthcare, especially the aging population and the challenge to fill their needs, these findings sound promising.

Authors of a systematic overview of quality and safety of care with the use of tele healthcare concluded, that evidence about patient safety and cost effectiveness were rare [47].

Further state of the art technology approaches are presented in chapter 2.4.3 State of the art.

[6] Technology Acceptance Model

[7] Perceived Usefullness

[8] Perceived Ease Of Use

2.2 Prevention & health promotion

The aim of this chapter is to provide an overview on the terms prevention and health promotion. These terms are relevant to understand the intention of this paper. Finally, further information about knee injury prevention provide a holistic picture of this topic and show the connection between these issues and the investigation.

2.2.1 Definitions and fields of application

The fundament of prevention and health promotion is epidemiology. This term describes causes and impacts of health complaints and thinkable interventions to improve and the health status of concerned population groups. In comparison to clinical medicine, which sets its focus on the individual, epidemiology sets the focus on the health status of a specific group or the whole population. A specific aim of epidemiology is to investigate the health status, doing health surveillance and investigate epidemics and disease outbreaks and their causes and dissemination. Useful implementations can be found in indentifying possibilities of preventing specific health problems or potential diseases or injuries [16, pp. 55–58].

Bittencourt et al (2016) conclude: „Injury prediction is one of the most challenging issues in sports and a key component for injury prevention.“ [48]

Authors of this quoted study, which present a new concept for identifying sports injuries, determine that most of human health conditions are complex and the nature of sports is too. It is recommended to move away from the classical risk factors, but towards recognising risk patterns instead. These patterns are defined through a so-called „Web of Determinants“, which consits of various and individual risk factors form regularities that in turn describe the emerging pattern. [48]

What is the difference between prevention and health promotion?

Prevention describes all interventions that try to *prevent* deseases and injuries, reduce their progress, or the reduction of consequences of existing diseases and poor health. Health promotion describes proceedings that support safety factors and ressources of humans in the context of health promoting living conditions and health behaviors. It is provided through social interaction, such as consultation or campaigns [36], [49, p. 5].

The conclusion is, that health promotion and disease prevention can be distinguished conceptually, they can hardly be distinguished in practice. Most general measures do both at the same time [50].

Data of epidemiology state a worldwide increase of chronic degenerative diseases. In Europe, 85 % of all deaths are caused by uninfectious diseases and 80 % by chronic diseases [37, pp. 8–15].

Considering social impacts on health, family and people around an individuum are much more relevant on “producing” health, in relation to health institutions. That is not to say, that the institutions are useless, but there is a huge potential in keeping people healthy and influence their health status, due to social impacts [37, p. 29].

As mentioned above, there is a change in the causes of death and the foregoing diseases and medical history. People get older, but also more ill. They live more ill years. To conclude, there is a shift from high mortality to a rising morbidity. But there are ways to prevent this negative development. There is good evidence, that moderate activity done five time a week has positive outcome on the health status. These are for instance: less coronary heart diseases, less perceived complaints, more satisfaction. Despite of these facts, only 10-20 % of citizens do the recommended amount of activity to achieve the mentioned health benefits [37, pp. 143–162].

The overall aim of public health measures is the strengthening of the peoples´ health competence. In the healthcare sector, an informed patient is the goal of these considerations. To get to this point, theoretical and pracitacal patient training should be absolved. These are efficient and effective measures. From the perspective of public health, the duties lie in research, practice and evaluation to develop interventions, which are customized to the needs of the citizens [37, pp. 379–389].

What is the role of medical technologies in this field and what are the costs?

As mentioned, the Kinect can be implemented as cost-effective tool for healthcare. The role of digital technologies is getting more important and dominant in various healthcare sectors. Health apps, fitness tracker and the more and more upcoming voluntary providing of personal health data are common in the populace. Smartphone, data glasses and digital platforms for healthcare providers are seen as companions for the digital revolution [51]. Although the Kinect has failed in the gaming sector, it is now used and investigated in healtcare [52]. The hardware itself (Kinect sensor) is available for about 100 Euros [53]. Optional costs to run a system senseful, are the expenses for a fully HD ready screen, a computer that can perform and compute the joint detection and an optional gameplay. Finally, an individual software is needed that fulfils the need of the individual field of application.

Cost-effective in the context of (digital) technologies in healthcare means keeping the allocation of ressources as low as possible with a maximum of outcome in health or health supply [37, p. 495].

To conclude, applications of digital technology in healthcare can be cost-effective and effective concerning the outcomes. Especially the Kinect sensor offers a convenient variant for the use in prevention and health promotion, because costs are low and the application is easy. As this system does not require any marker on the body, no expert knowledge is needed in preparation, and even more important, it is very time saving. This is important when it comes to the application in the clinical practice, where time is valuable. One approach could be the use of i4Ski as a preventive method in physiotherapy as a preparation for skiing or other exhausting activities that demand stability and strength in the muscles of the lower extremity. The advantage lies in the playful entry into the training programme and that only little prior knowledge is needed. This is an important fact, because many people, especially elderly fear new technologies for various reasons. Often, because they feel overstrained. In this game, a concise introduction gives an overview of all game functions and explains the gameplay.

Further possible applications can be seen in the use of i4Ski in general health promotion. Individuals that are interested in improving and retaining their general health status or want to strengthen their muscles, could play the game in a therapy setting. Possible benefits may be seen in prevention of cardiovascular diseases and diseases of the musculoskeletal system, such as arthritis.

2.2.2 Prevention

The term prevention can be split up in three parts: primary, secondary, tertiary prevention. The latin verb ‘praevenire’ can be translated as pre-empt or obviate (something). Primary prevention refers to healthy individuals. Examples are vaccinations, hygienic prophylactic actions, healthy food or early childhood sensomotoric promotion. Secondary prevention refers to an early diagnosis of diseases, for example breast cancer screening or eye checkups. If there is already set a diagnosis, tertiary prevention can be used to hold the health status of the patient. In general, the purpose is to prevent or minimize negative secondary diseases or chronification. This field interfaces with the field of rehabilitation [54, p. 12].

Prevention is the avoidance of diseases or injuries through targeted activities. It concentrates on preservation of health and the contraception and early detection of diseases [37, p. 198], [41]. The already mentioned primary prevention is the matter in this work.

The objective here is to implement measures on healthy individuals to prevent the risks of knee injuries. As already mentioned in the introduction, ski-related knee injuries are a big deal for the healthcare system. The most common ski related injuries occur on the knee joint. The two most common injuries here are tears of the MCL[9] and the ACL[10] [9]. The average expenditure for ACL refixation surgery amount of approximately $ 16.000, not including the follow-up rehabilitation and long-term expenditures. Conservative approcaches, that means an option without surgery but with physiotherapeutical treatment, cause costs of about $ 15.500 [55]. After ACL tears, with or without refixation surgery, the chance to suffer from arthritis of the knee joint is more likely than without that kind of knee trauma. [56], [57].

There is evidence that preventive interventions can be very cost-effective. Authors of a study, investigating the effects and costs of a knee prevention programme in soccer calculated costs of $ 25 per player for one season. With a general training programme, that can be implemented in every type of sport, the rate of injury can be reduced from 3 % to nearly 1 % [58]. Considering the expenses for the treatment of ACL injuries and subsequent costs for the health system, the presented expenses in prevention are absurdly low and therefore provide an extreme cost-effective alternative.

The American Physical Therapy Association recommends appropriate exercises like stretching and strength building for muscles of the lower extremity. These measures could lower the rate of ACL injuries [59]. Programmes that focus on the neuromuscular control can reduce this risk. This can be implemented through a simple warm-up programme before sports [60].

To conclude these findings, preventive knee training is cost-effective and easy to implement. There is good evidence, that targeted exercise can reduce the risk of injury, especially of the ACL, which has been discussed above. To tie up with the issue of this work, the developed game could be used as a tool for strengthening the thigh and gluteus muscles and to improve the neuromuscular control of these muscles. In case of positive outcomes of investigations in this work, the game can be seen as a cost-effective tool for the healthcare system and may therefore be implemented into standard care for prevention, but also in sports, to help sport clubs and athletes to decrease injuries and therefore safe money and energy.

[9] Medial collateral ligament of the knee joint

[10] Anterior cruciate ligament in the knee joint

2.2.3 Health promotion

The Ottawa-Charta from 1986 describes health promotion as “the process of enabling people to increase control over, and to improve, their health. To reach a state of complete physical, mental and social well-being, an individual or group must be able to identify and to realize aspirations, to satisfy needs, and to change or cope with the environment. Health is, therefore, seen as a resource for everyday life, not the objective of living.“ [61]

Health promotion aims at processes, enabling all human higher autonomy regarding their health to empower them to strengthen their health. Patient empowerment is called a process to regain self-determination of control of individual living conditions. Health promotion can occur across the whole healthcare spectrum, from a population-wide level, through to a community level and an individual or clinical level. Overall, the focus is more about general policy, society and political measures [37, pp. 189–191].

2.3 Medical background

This part of the paper gives explanations of anatomic structures, functional parameters, diseases and possible injuries of the lower extremity, especially the knee joint.

2.3.1 Body planes

To understand basically how movements are mesarued and understood in the medical field, the following figure (Fig. 2) describes the three planes of the body. In daily healthcare practice, there are more utilized descriptions to localise body parts and to describe movements, but in this work, these basic planes are sufficient to explain the matter adequately.

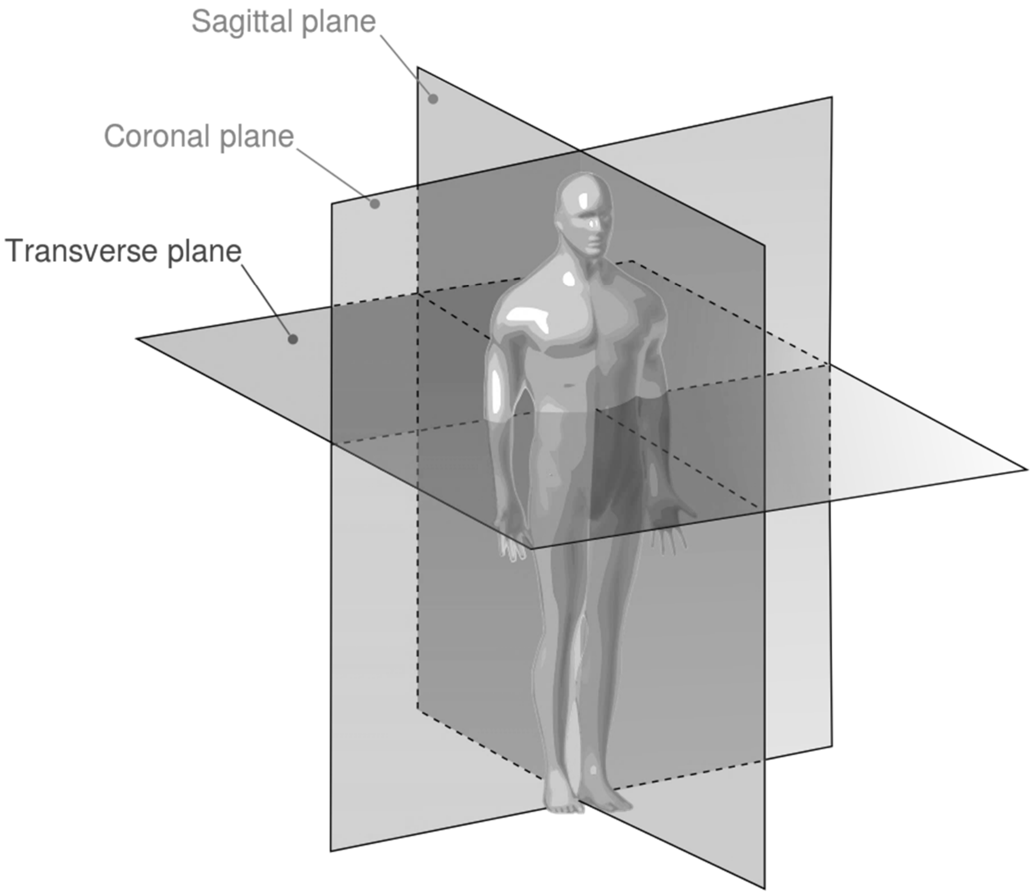

Figure 2: Human anatomy planes, unrestricted use [62]

These three planes describe positions and/or movements of body parts, in example joints or body axes.

2.3.2 Knee joint

The knee is described as so-called joint gear system, a special type of portable hinge joint. The main motion of flexion and extension consists of rolling and sliding of the joint surfaces [63, p. 206]. Rotational movements occur in the axial plane, when the joint is not in full extension. Due to the tension of the collateral ligaments and the ACL, the knee can not be rotated in extension. In the last ten degrees before full extension the knee does an external rotation of five degrees [63, p. 212].

It is important to mention, that movements ususally take place in more planes – they are complex combined movements. To provide stability and control in joint motions, active (e.g. muscles) and passive (e.g. ligaments) structures work together [64].

2.3.3 Mechanical axis

The MA[11] of the lower limb is a line that crosses the joint centres of hip, knee and ankle. The HKA[12] is also called the Mikulicz-line and equals 180° in theory. The physiological HKA of the leg is 173-175° on average, which is a displacement of the knee joint in the medial direction, considering the Mikulicz-line [65, p. 410], [66, pp. 327–28], [67]. This kind of approach of the MA is applied in this work and calculations of the Kinect.

2.3.4 Anatomic axis

In contrast to this, the AA[13] is defined along the bone structures. The line runs along the shaft of the thigh bone until it hits the knee joint. Calculating the HKA with this procedure, the angle of the axis equals other results than calculations of the mechanical axis, but on the same structure. An average angle of the axis with this approach is 168° [67]. This does not mean, that the structures changed, but the calculation is different on the same anatomic structures. The difference of these calculations is shown in Figure 3.

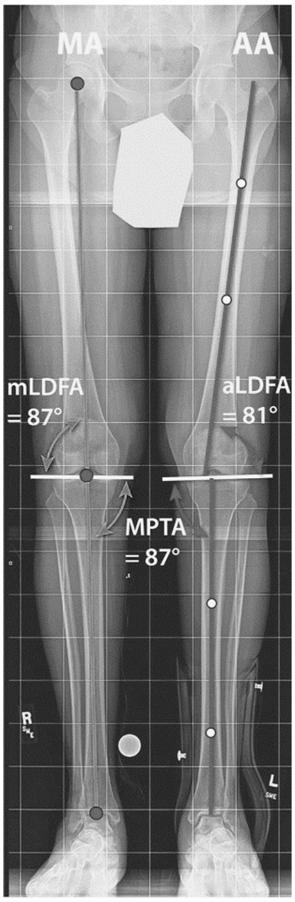

Figure 3: HKA [63]

2.3.5 Pathological malpositions

For a better understanding of the physiological and pathological functions of the HKA, common malpositions of the knee are described below. In the coronal plane, two types of pathological knee positions can occur. If the center of the knee is displaced in the lateral direction in relation to the physiological axis, this is called genu varum (colloquially “bowlegs”). If the center of the knee is more medial than physiological, this position is called genu valgum (colloquially “knock knees”) [66, p. 328], [65, pp. 410–11].

11 Mechanical axis of the lower limb

12 The straight line over hip, knee and ankle.

13 Anatmoic axis of the lower limb

2.3.6 Static HKA

The positions stated above are concrete diagnoses and can be detected via X-ray of the whole leg. If a malalignment is diagnosed this way, the malposition is structural. This means, that pathological deviations of the bone and joint structures take place and can only be changed through surgical procedures, e.g. a total knee arthroplasty [67]. An exception are babies and small children, which have other HKA positions through upgrowth and a steady change of the bones and the resulting leg axes [65, p. 411].

In an investigation of more than 11.000 radiological diagnostic findings, the impact of structural malalignments of the axis has been shown. If the axis is incorrect 1-3° in medial direction (genu valgum), there is high risk that complaints in the lateral knee joint occur. More than 3° outside the physiological axis positions causes damage on the joint cartilage and the meniscus of the lateral knee joint [68]. Deviatons of the HKA must be taken serious, especially in the growth phase, because it leads to irregular load of the joint surfaces and subsequently to osteoarthrosis [69, p. 68].

2.3.7 Functional HKA

Analysing the HKA and possible functional deviations by observation is the main job of a physiotherapist, which treats people with complaints in the lower extremity or clients with preventive needs. The diagnosis takes place in the context of the physiotherapeutical functional demonstration. Here, the patient/client shows his abilities and disabilities. The therapist analyses the biomechanic of the HKA statitcally as well as in dynamic movements.

Stability of the knee joint, especially in the coronal plane is an important factor considering the optimal load and use of osseous and ligamentous structures. If the joint is in an unstable flexed position, the risk of injuries of ligaments and meniscus is increasing [69, p. 64].

The more valgus stress comes up in the knee, the more the medial ligamentious structures are strained. It is important to avoid ruptures of knee ligaments, because this leads to instability of the joint. Besides the ligamentous structures, the full and physiological function of the quadricpes muscle is crucial to avoid knee instabilities [69, pp. 106–108].

Cutting or sidestep maneuvers are associated with dramatic increases in the varus-valgus and internal rotation moments. The ACL is placed at greater risk with both varus and internal rotation moments.

The typical ACL injury occurs with the knee externally rotated and in 10-30° of flexion when the knee is placed in a valgus position as the athlete takes off from the planted foot and internally rotates with the aim of suddenly changing direction. The ground reaction force falls medial to the knee joint during a cutting maneuver and this added force may tax an already tensioned ACL and lead to failure. It may be, that the addition of valgus knee position and/or rotation could trigger an ACL rupture [70], [71].

The knee sustains the highest percentage of injuries. Considering the HKA and its participating joints, the hip muscles, especially when they are weak, play an important role of the function and biomechanics of the knee joint. [72]

A straight leg axis makes up 50 % of the anatomic correct coordination of the lower extremity. The functionality of the HKA is ensured with the strongest muscle chain in the human body, composed of the gluteus muscles (M. gluteii) on the hip, quadriceps muscle (M. quadricpes) for the knee and the triceps muscle (M. triceps surae) on the calf for the ankle [73, p. 222].

Specific leg axis training can counteract incorrect loading on the knee joint. Problematic movements and dysfunctions can occur in multidimensional ways. The mentioned (structural) malpositions in the frontal plane (genu varum/valgum) cause an overload of the articular cartilage of the knee and lead to damage in the cartilage and one-sided osteoarthritis. In the transverse plane, hypotorsion (too little rotation) leads to inner rotation of the thigh and external rotation of the shank. This causes a pathological genu valgum and overload of muscle insertions and the colleteral ligament on the medial side [73, p. 224]. To correct axial dysfunctions of the HKA, the knee is in slight flexion and the thigh is externally rotated. The patella (knee cap) points forwards in this final position [73, p. 228].

Reviews of clinical and biomechanical studies in the field of knee injuries and the influence of proximal factors indicated that impaired muscles of the hip joint, pelvis and trunk can affect knee joint kinectmatics and kinetics in multiple planes.

There is evidence, that impaired hip movements may underlie injuries as ACL tears, ITB[14] syndrome, PFPS[15] and osteoarthritis [72], [74].

[14] Iliotibial band syndrome

[15] Patellofemoral pain syndrome

The hip joint plays an essential role in the functional group of the HKA, especially its influence on knee pathologies. Abnormal hip motion can influence the kinematics of the tibiofemoral joint directly.

Excessive adduction and internal rotation of the hip in the supporting leg can cause a movement of the knee joint to the medial side in relation to the foot, which is fixed on the ground [72].

In a consequence of this, excessive transverse and frontal plane motion take place at the hip. This results in a dynamic knee valgus. A relation between knee valgus and weak hip muscles has been pointed out, as well as knee injuries like ACL tears and patellofemoral joint dysfunction. High valgus moments have been shown to be associated with reduced strength of the hip muscles. Concluding this, proximal dysfunction may accord to knee joint injuries. There is evidence, that diminished hip muscle strength may contribute to ITBS. Investigations reffering to the PFPS suggest, that the control of rotations of the femur may be important in resporing normal patellofemoral kinematics. These findings indicate that interventions on proximal impairments, as mentioned hip muscles that rotate externally and do abduction and extension, may be beneficial for people who show a dynamic knee valgus. The gluteus maximus muscle provides 3D hip stability, as it moves the hip in the movements mentioned above. This muscle protects the knee from proximal movement dysfunctions. Another stabilizing muscle on the hip is the gluteus medius muscle. But, with more hip flexion, e.g. during executing a squat position at 60°, the external rotation is produced and controlled less by the gluteus muscles in this position. It can be concluded, that at dynamic hip flexion position, dynamic hip controls are more challenging, but nevertheless even more important in a flexed position. [72]

Pursuing to findings above, increased adduction and internal rotation of the hip joint can increase the risk to suffer from PFPS. Strenghtening of the antagonist hip muscles, hip abductors and external rotators is recommended to treat and prevent PFPS. Increased valgus of the knee, which can occur in function, when muscle groups mentioned above are too weak, can cause ACL injuries and ITBS [74].

2.3.8 Differentiated learning

As depicted above, not only muscle strength, but also motor control of hip and thigh muscles is essential to optimally load the knee and prevent injuries. The theory of differentiated learning deals with motor learning and methods of a successful implementation.

Increasing fluctuations, critical variability in phase changes and initiated self-organisation are key components of differentiated learning. Through increased variability the exercising subject can choose the optimal mode for his individual conditions. Differentiated learning delivers an approach for a more richly varied learning as common learning models. Fluctuations in movements are constructive elements for learning. The method of differentiated learning already takes place in sports and physiotherapy [75].

The approach of variability in learning of movements is dicussed in the paper of Schöllhorn (2015). The model of differentiated learning describes a process in which a new motion or sports is learned. The executing subject can variate the movement and can so benefit from different variations of a new movement. In contrast, rigid movement patterns do not provide these benefits. Here, the impact comes external and with differentiated learning from the inside.

An initiation of self-organisation is wanted. An increase of variated movements leads to better performance and improves the body senses instead of focusing on external feedback and movement information [76].

2.3.9 Parallel back squat

The squat exercise posture, which is demanded in the developed skiing game and in many other activities of daily living, like sitting up and down from a chair or lifting heavy objects, is a common exercise that is used for strengthening muscles of the lower extremity and the trunk. Especially the gluteus maximus and quadriceps muscles are big muscle groups, that are required in this movement. As mentioned above, these muscles are crucial to prevent knee injuries and for an optimal load of joint structures.

As the developed game adjusts a ski run from a mountain, the required position in the game should be as similar as possible to activate the same muscles, generate the same feeling and to prepare for the real situation. For these reasons the chosen movement is a parallel back squat with outstrechted arms (see also fig. 4). With parallel legs, skis do not brake the run and offer the optimal ground contact.

The outstrechted arms position has been chosen to not interfere with the HKA joint recognision of the Kinect. Secondly, this arm position helps to keep balance when performing the parallel back squat.

This is necessary, because the flat position in a room differs from the slope in real skiing, where the center of gravity is different.

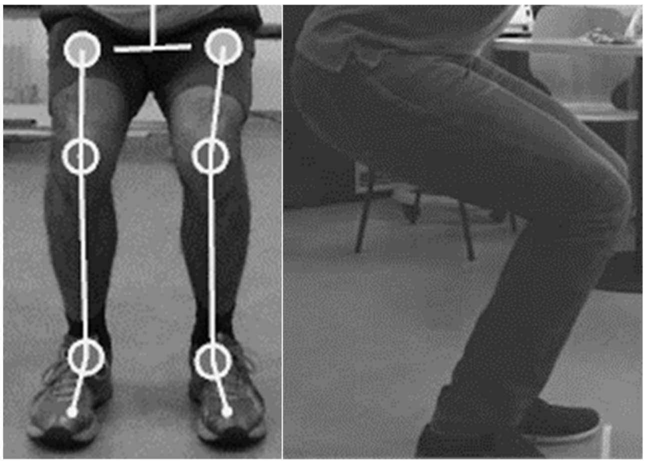

Figure 4: Parallel squat, front and side view

There are various kinds of squat techniques and positions, but nearly all of them provide physical improvements and reduce the risk of injury. Although there is little evidence for the unloaded parallel back squat, a very common technique is the loaded or unloaded back squat. The main difference is the hip rotation, which is in neutral position in the parallel back squat. Hence, this is a more ADL-like movement and the skiing position can be simulated more accurately than in other squat positions. The back squat is a position with more external rotation in the hip and the standing position is wider, which delivers more support surface. Unloaded positions can be used as a screening tool for the therapist to detect malpositions in the biomechanics [77].

The depth of the squat position is an important factor. In healthy individuals, a parallel position as provided in the game is a beneficial movement. A correct performance of squats can increase the knee stability and the participating muscles of the lower limb [78].

Furthermore, this exercise position can be used to prevent and reduce complaints on the lateral knee joint like PFPS. Authors of a recent published study concluded, that a flexion angle of 60 ° is the most effective position for a squat exercise. For patients with limited joint movements, unstable grounds and a knee flexion angle of 15 ° already provide an adequate training [79]. The more knee flexion is executed in the parallel squat position, the more muscle activity has been measured in gastrocnemius, ischiocrural and quadriceps muscles between a range of motion from zero to 100 degrees [78].

2.4 Technical background

In this chapter, an overview of applied hard- and software and state-of-the-art of science and technology is given.

2.4.1 Hardware

The Mirosoft Kinect II sensor uses a 1080p HD camera, an infrared emitter and infrared sensor to calculate a 3D image of the detected object. It is a compact device with the following dimensions: 24.9 cm x 6.6 cm x 6.7 cm (length x width x height), see also figure 5 [80]. The sensor has initially been meant for the use in games in combination with the Xbox from Microsoft. Later, development kits for Windows has been published [81]. As mentioned in chapter 2.2 prevention and health promotion, the implementation in the gaming sector for end users failed [52].

Up to now, it is widely used in development and research in medical concerns. It is easy use, the low asset cost and the freely available development environment provided from Microsoft makes it a popular device. For tracking joints, no makers on the tracked body are required and calibration process is quick and stable [82].

Figure 5: Kinect II sensor [74]

The following table (Tab. 1) shows the utilized hardware in the implementation phase of this work and the fundamental technical specifications:

Device	Dimensions	Equipment
Microsoft Kinect II	24.9 cm x 6.6 cm x 6.7 cm	Infrared depth sensing 512 x 424, 30 Hz

		1080p RGB color camera, 30 Hz
LG smart TV	Screen: 46 inches	Max. resolution of 1980x1020 px
Laptop		Intel core i5, 8 GB RAM, GeForce 840M

Table 1: Hardware specifications [83], [80]

Various studies conclude, that there are notable advantages in the use of a Kinect system. It is generating motions quick, it does not need any markers on the tracked body, users can learn to handle the system easily and fast, it is cost-effective and can be moved or transported easily, tracked joint points are close to their actual positions on the body. [82]

If there are joint overlaps, the Kinect sensor is not accurate enough in tracking and locating the correct joint positions, so these movements should be avoided. Secondly, to close performance in front of the Kinect sensor do not work well. A distance of minimum 1.5 meters is recommended [82]. According to these data, a distance of exactly two meters and the above described arm positions to not overlap hip points, has been chosen.

Instead of using RGB[16] sensors, the Kinect is based on depth imaging that provides a Software Development Kit (SDK) which gives access to skeletal tracking data and can be used directly in rehabilitation game developments [81].

2.4.2 Software

The development work of the game has originally been done by Martina Strohmayer within the bachelor programme media technology. From the beginning of the cooperation to further develop the programme, the library from Thomas Sanchez Lengeling, KinectPV2 has been used for tracking the joints. It functions on Windows10. As a new development environment, Processing 3.3 has been chosen. The software development kit (SDK) of the Kinect V2 detects human shapes.

[16] These are colour-sensors, having a 3-channel (RGB) photodiode sensitive to the blue, green and red regions of the spectrum

2.4.3 State of the Art

Since the release of the Kinect 2 sensor in September 2014, more and more investigation has been done with the developed hardware for the use in healthcare. The field of application ranges from simple measures of joint movements to complex approaches with patients suffering from neurological deficits. The presented literature research delivers the advantages and disadvantages, possible and useful applications and gives an overview of other markerless and/or markerbased body detection systems.

Kinect II is a safe and cost-effective device for healthcare, although it is not an originally medical imaging device. The originally main intension was for computer gaming with the Microsoft Xbox console. The sensor shows adequate performance for a range of healthcare applications in a cost-effective way [8]. Comparing the costs of VICON and Kinect, huge price differences come to light. While a Kinect sensor can be ordered directly from Microsoft for about 100 Euros [53], the Vicon camera and IMU sensor cost about 21.500 Dollars [84]. Besides the low acquisition costs, Kinect systems have the potential to provide cost-effective applications for healthcare [8], [85].

Advantages in the use of the Kinect are the portability, quick set-up, quick implementation in the practical use, also because there are no markers needed on the body. In turn, this safes time and therefore costs, because the installation of markers on the body is time-consuming. Furthermore, the good accuracy in joint and motion detection is stated as beneficial aspect in the use of this device [82], [86]. Additionally, increased usability of the Kinect has been investigated, compared to the Vicon system. [87]

Up to now, marker-based systems have been used as a precise and accurate method for capturing motion. Attaching markers may offer some problems, and consequently, a new concept, based on a marker-less system, has been developed.

Compared to the gold standard, the Vicon system, the Kinect shows competence, adequate accuracy and clinical acceptable data in the use of motion tracking, for example in gait analysis or for fast recognision of the body morphology [88], [89], [90], [91]. Autors of a study, which investigated if the Kinect is accurate and reliable stated, that their results had been generated with young and healthy adults [89]. An example of the difference in tracking of the body as base of joint and motion calculation, is presented below (Fig. 6).

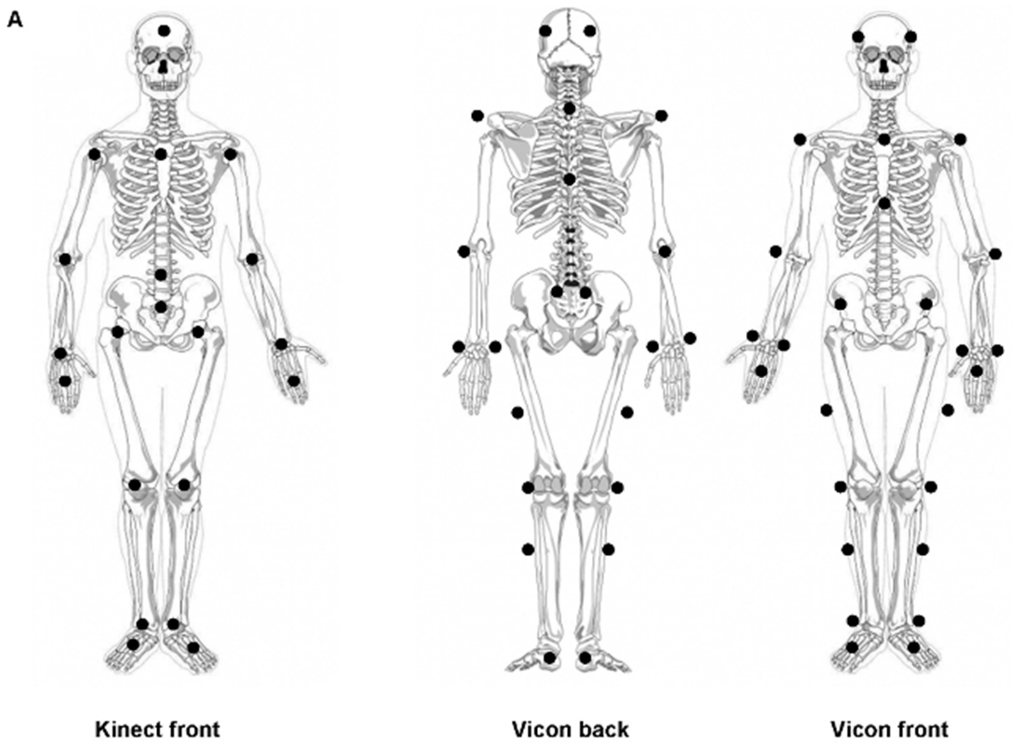

Figure 6: Comparison of tracking points, Kinect vs. Vicon [82]

For a variety of motions, the Kinect shows good outcome compared to the Vicon system. [92].

Compared to the so-called Optotrak motion-registration system, another marker-based tracking system, the Kinect can be used to observe the 10-Meter Walkaway and can detect walking speed, step length, cadence and many more, accurately. [93]

The Kinect showed execellent results for gross movements, like sit-to-stand [92], whilst standing positions can be measured more accurately than sitting positions [94].

Currently, there is a lack of information in the use of the Kinect in practice. An information system, named "KWiC" ("Kinecting With Clinicians") was created to investigate the usability of the system among clinicians. 16 participants with little experience in Kinect games in the clinical practice were asked to give feedback. The idea is to get clinicians ready and the will to use technology – not only because it is popular or the latest state of the art, but to use it for the patients' benefit. Therefore, it is essential, that therapists can handle the software (and hardware) and can explore the proper features of given programs. Furthermore, it has to be proved, that evaluation of the effectiveness and adaption of the given programs for the individual needs of patients can be handled by clinical staff.

Results show, that the participants reported positive responses about the KWiC information system. The authors came to the conclusion that clinicians need support to adopt the researched technologies into practice. [95]

Parameters like gait, balance, quality of movements or motor performance are crucial parts for decision making for clinical parameters and the anamnesis. To recognize and adequately process and correct these complex body movements, a tracking system must be accurate and must run stable and reliable. Kinect-based systems showed in studies significant improvements in motivation, gait parameters, muscle strength, balance and motor performance. Various studies conclude, that the Kinect can be used in the clinical setting [96], [81], [97], [98], [87].

Considering the fact, that especially measurement of knee valgus motion suffers of less accuracy and that ACL injury is strongly connected with knee valgus position, further development will be necessary.

The results show, that there is a variety of significance in the use of Kinect-based systems with patients and healthy people. But there are also results that demonstrate, that this system is not the best choice in each field, or that further studies should be done to get reliable and valid results, especially in the field of prevention and health promotion and in usability purposes.

3 Prestudy

This chapter describes the prestudy, which has been accomplished within the first three semesters of the master programme digital healthcare. The aim of this project was to develop promising ideas and existing approaches in digital healthcare from the entrance examination process of the students. Most promising and popular conceptions have been chosen and appropriate groups of students have been formed in a so-called World Café. In this process, project approaches have been introduced and possible task groups were built. Together with Samson Pusswald, Doris Thumfart and my person, a team of physiotherapists, investigated the technology acceptance of practicing physiotherapists of a Kinect-based whole-body training programme. The project started in September 2015 and ended with a final presentation of the results and submission of a paper in February 2017 (Fig. 7) Based on the results and conclusions, I decided to carry on investigating possibilities on developing and evaluating Kinect-based training programmes.

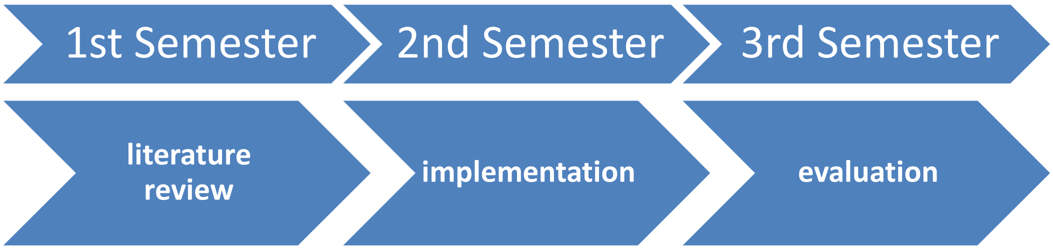

Figure 7: Project process of the prestudy

As we noticed in the preselection of the exercises, we wanted to be executed by the study participants, exercises on the lower extremity worked well. Especially exercises targeting the knee and the mechanical axis of the leg worked adequately. We found that the detection of the joints of the lower extremity (hip, knee, ankle) and the calculation of the mechanical axis was adequate. But, this was just our subjective perception as physiotherapists and we did no further validation.

The main purpose of the mentioned study was to investigate the technology acceptance amoung other physiotherapists. In a practical trial, a Kinect-based rehabilitation system from ATOS, an Austrian provider of healthcare IT solutions, has been tested by physiotherapists. Subjective impressions were queried with a questionnaire.

The developed questionnaire contained independent variables like social and cognitive influence, demographic data, determinants from the TAM[17] and psychological factors. A dependent variable was defined as the variable which was influenced by the independent variables. The variable was modelled as a function of attitude toward using and perceived usefulness and determined an actual use. We received realiable data from 29 participants. Existing raw data were processed with descriptive methods.

Relying to the knowledge resulting of our trial, well-grounded decisions for a possible implementation in healthcare systems can be taken by clinicians and responsible persons in healthcare. On the other side, valuable data can be given to the program developer to potentially set improvements on usability.

Recently, scientists and practitioners from the field of human-machine interaction and usability engineering have emphasized the importance of an extended holistic concept of quality [99]. Other important quality aspects, like aesthetics, enjoy using or appropriate challenges, are responsible for a complete success of an interactive product. So far, such hedonic aspects of existing quality management processes have been ignored. In the context of simply work-related software, an influence of perceived pleasure in use can be shown to the acceptance of the software. In this context, hedonistic aspects have motivating effects [99].

Another important aspect is a similar understanding about the role of emotions when using interactive systems and systematic approaches. A modification of non-instrumental quality assessments and emotional aspects of the user experience should be discussed [100].

Demographic data, like working experience, age, language, routine with a computer, playing with a computer regularly and already using technology supported treatments in work have been analysed. Also, aspects of perceived usefulness, perceived ease of use and emotions were regarded as independent from each other.

A cluster of results of specific statements and an execution of interclass correlations should lead to required results for in-depth analyses and finally to drawing conclusions with regard to the TAM. Considerung the emotional factors of physiotherapists on using a Kinect-based rehabilitation programme in (Fig. 8) there is little technology anxiety and scepticism.

[17] Technology Acceptance Model by Davis (1989)

Curiosity about the mentioned technology among physiotherapists is balanced. We could not find significant correlations between age and curiosity.

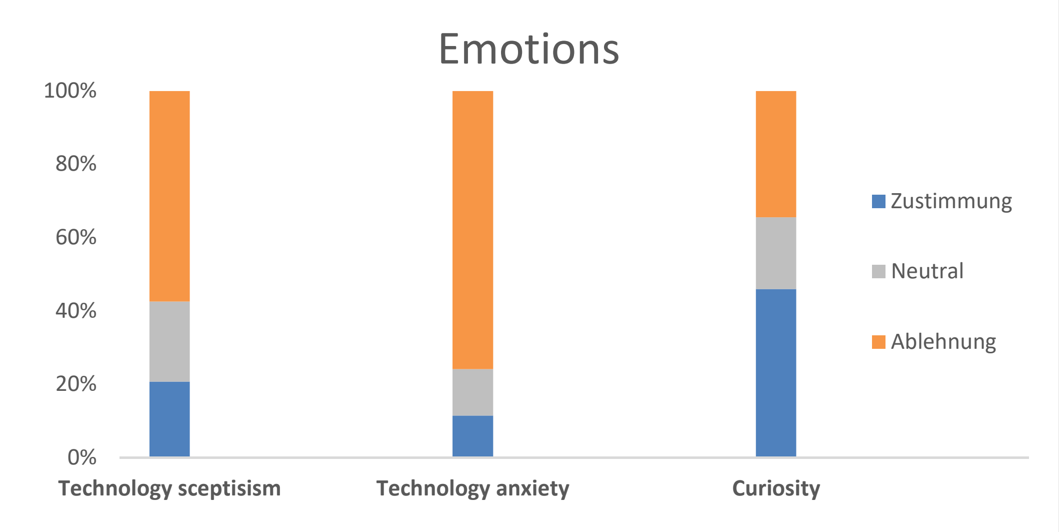

Figure 8: Emotions in context of using VR games of ATOS

The determining variables of the intention to use were the main aspects of the prestudy. They describe the probability of a physiotherapist to actual use the tested technology in the clinical practice. It is composed of three factors, that have been investigated separately. Every item again consists of three statements, that had to be rated by the participants. The average values of these statements have been summed up and plotted below (Fig. 9).

Social norms do not have an impact on the intention to use the technology, whilst the perceived usefulness shows high impact.

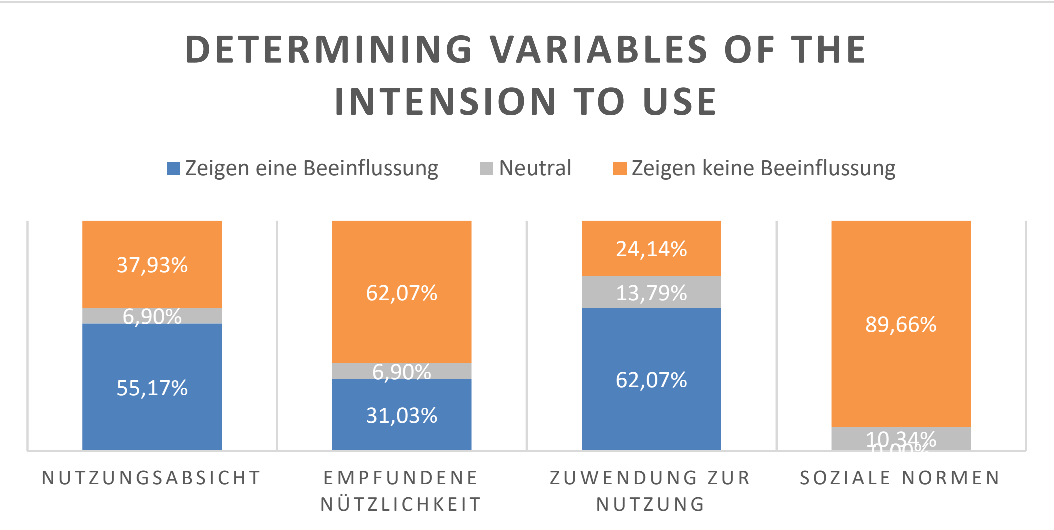

Figure 9: TAM model in context of using VR games of ATOS

The following hypothesis were specified by data analysis and interpretation:

H1	Social norms do not have an impact on the intention to use.
H2	Psychological factors have no influence on the behavioural intention to use.
H3	Little technology interest and/or little perceived usefulness do not have a great impact on the intention to use the system.
H4	Increasing age has a negative impact on intention to use.
H5	The data of attention toward using correlates with data of the intention to use.
H6	The less technology scepticism, the higher the intention to use.

Table 2: Hypothesis generation from prestudy

Despite the descriptive nature of this prestudy, it was managed to elucidate an overview of technology acceptance of physiotherapists by testing virtual rehabilitation. The perception constructs of TAM shall help to set light on the type of technical products that are intended to be purchased by health-professionals.

4 Development of the prototype

This part of the work is about the further co-development of i4Ski, a Kinect exergame, which intentions were originally to increase muscle endurance and to alleviate fears of knee injured persons, who once suffered from a ski trauma. In October 2016, Martina Strohmayer, student of the bachelor programme digital media and I decided to further develop and evaluate this partly existing game, initially developed by Ms. Strohmayer using a Microsoft Kinect I sensor. The intention was to build a cooperation between digital media and digital healthcare expertise. With this step, a multidisciplinary cooperation has been established to overcome obstacles that occur when one experts' knowledge is insufficient to implement an extensive and multidisciplinary project. A project in which a product is created, that is innovative and underpinned with specialist knowledge and evidence based data at the same time.

4.1 Interdisciplinary cooperation

4.1.1 Background

The first step in the development phase of the project was a brain storming to evaluate the conceptions and ideas that each team member at this point. The conclusion of the brain storming was, that an accurate prototype knee training programme with the Kinect II for preventive purposes will be further developed and evaluated. The focus of Strohmayers work was to further develop the game and to measure the accuracy of the Kinect sensor while tracking the leg axis. As comparison, the software programme 'Kinovea' has been used to evaluate the accuracy of the angles of the knee joint.

A literature review revealed, that there is still poor evidence of usability of Kinect-based training programmes and a need for further scientific findings in this field [95]. Although there is a wide field of applications, as stated in chapter 2.4.3 (State of the Art), this hardware is only rarely used in healthcare. Besides cost-effective acquisition and acceptable accuracy in motion recognision, a relatively new digital technology also must be usable in practice. That means, that it has to meet the users expecatations, it has to be effective as well as efficient for the users' purposes [101].

For the implementation, the hardware has been switched from the first to the second version of the Kinect sensor, which is the direct successor of the original Kinect.

The original game did not calculate and correct malpositions of the HKA with a medical background. This was the biggest part of work – to generate and develop an adequate HKA range, that is evidence based and sensible, considering the technical parameters. This process is described in the chapters below.

The basis of the prototype has been developed by Martina Strohmayer, which is student of digital media on the FH St. Pölten. Her intention was to help people that already suffered from knee complaints like she did after an injury from skiing. She felt that the emotional part from getting back into skiing after a traumatic situation is the hardest part, even more than doing months of rehabilitation for the knee joint and building up muscles and the health status.

The aim of the cooperation was to further develop the existing ski exergame with the expertise of two different disciplines. The game should be used in the field of health promotion and prevention within a physiotherapeutical setting. Secondly, it should fulfil the medical requirements of a correctly recognised HKA and knee flexion. To approve this, accuracy measurements were planned to manually measure the HKA and knee flexion and then compare these data with the automatically generated angles from the tracked joints. Finally, a usability evaluation has been planned, to find out, if the developed prototype is usable from the perspective of experts in human motions – physiotherapists and sport scientists (see also chapter 5 methodology).

Considering principles of feedback and motor learning, i4Ski provides a training programme that sets the focus on extrinsic feedback. Investigations on giving extrinsic feedback has been shown, that it supports motor learning more effectively than no feedback or intrinsic feedback [102]. Extrinsic feedback is defined as knowledge of results or performance, that reaches the user externally – in this case live motion data from a screen. On the contrary, intrinsic feedback comes from the sensory and perceptive system of the user, without any information from outside the body [103, pp. 136–37]. In i4Ski, the users get visual feedback, based on their motion and body posture. We did not use more input channels, for example auditory signals for good or bad HKA, or sensory feedback in form of wind blowing in the face when the driving speed is increasing. The reason was, that an overload on feedback in frequency and types of feeback can decrease performance [104]. Another reason was the difficult implementation of the mentioned elements.

The advantages of this system from the aspect of motor learning are, that users get real-time feedback and can therefore react instantly to deviations. To correct deviations, a performance-based bandwidth has been defined (see also 4.1.3 Adjustments). This bandwidth allows the user to choose the HKA position freely. As long, as the borderlines are not crossed, no feedback is given. Instead, acceptable errors are tolerated through the system.

The required back squat seems like a very easy movement. But it is a whole-body movement, that actives big muscle groups in the lower extremity and the core. Furthermore, controlling the HKA correctly in the given bandwidth is quite demanding, also for healthy and young people. In this case, a combination of actual and target values is recommended [105]. Consequently, both values are displayed in the game. When the user performes correctly, a green check is displayed on the screen. Otherwise, a failure symbol in form of a red ‘X’ is displayed and additionally, a text that describes how to correct the position is displayed.

Gamification in health applications is hugely popular, but a low adherence to professional guidelines and/or industry standards. There is a lack of integration of elements of behavioral theory, which could potentially spread health behavior change interventions [106]. For a better usage of behavior theory in health applications, collaborations between behavorial experts and applications designers are strongly suggested [107]. On the other hand, only 4 % of 1680 investigated health applications included gamification [108].

Through gamification, the user can experience a more intensive and realistic gameplay. Investigations on psychological effects after exercise showed that there is a significant decrease in negative affect and positive affects are increasing. Enjoyment was positively related to increases in positive affect but unrelated to changes in negative affect [109].

4.1.2 Accuracy measurments

In March and April 2017, accuracy measurements have been executed to develop a new calibration for the hip joint tracking that met my expectations. My part was to support Strohmayer with physiotherapeutical advice to adjust the new calibration. In the original gameplay, we noticed a systematic deviation of both hip points, that have been automatically defined by the software toolkit of Microsoft.

The calculated points have been too close to each other. The center of the hip joint was estimated to close to the detected bodies median line.

Five randomly chosen students of the FH St. Pölten have been instructed to perform three parallel back squats. They have been positioned in front of the Kinect sensor, with the same hardware setting and software basis as the original game was created. We tracked the HKA and let the system calculate the angles. After this, we manually measured the HKA and knee flexion with Kinovea.

In the sagittal plane, the knee flexion and extension was measured with the Kinect sensors. To compare the values, we used a side view video recording from the subject who performed a movement. Afterwards the angles of the knee joint have been measured manually with Kinovea and then compared in the same point of time.

In the frontal or coronal plane the same process has been implemented except that the video reording has been done directly in front of the subject and above the Kinect sensor, but in same vertival position. The data again has been compared and manually evaluated with Kinovea.

The results of Strohmayer showed for the knee flexion angle a standard deviation in average of 20,1° in the final squat position and 7° in upright standing position. The system calculated up to 20° more knee flexion than it was in reality. Measurements for the HKA showed deviatons of 4,2° for the left knee and 1,7° for the right knee [110].

4.1.3 Adjustments

Additionally, with the findings above, an offset of 25 pixels has been set to correct the systematic error from the original setting. That means, that for every individual calculated hip joints, an additional fixed offset has been chosen. This offset has been calculated from the data of the accuracy tests. It was the average deviation of the five probands. We first let the system track the hip points and the HKA and then manually measured the actual HKA again with Kinovea. After that, we did an indivudial correction on the hip joint tracking. The average offset here was 25 pixels to the lateral side, which Strohmayer then included into the algorithm. In figure 10, the difference between the two calculated hip points is presented.

On the left side, the original setting of the Kinect development kit determines the position of the hip joints. The right side shows the adapted calculation model with an offset of 25 pixels. This modification has been done because of the too closely set hip points in the original model, which led to a systematic error in the calculation of the HKA. When the hip joint is estimated too close to the body´s midline, the calculation of the HKA will automatically report more than the physiological 173-175° and then claim that the knees are too wide on the outside.

The consequence would be a constant, systematic error and an overcorrection of the knees towards the medial side, to correct the misleading malposition of the HKA. To prove this assumption, we recorded both settings and measured the HKA in both variants. With this method, we determined the offset for each individual proband in the implementation phase. These proceedings have been executed with Kinovea, a video analysis software dedicated to sport. We prepared the recordings and measured the HKA angles manually as they really were and compared it to the calculated angles from the Kinect system.

With the first position (Fig. 10, left side), we manually measured an HKA of 191° in an upright standing position versus 180°, that has been calculated from the system. Here, another weak point appeared: the calculated knee points where often set too far on the inside of the knee. The modified hip points (Fig. 10, right side) and the following calculation resulted in 179° HKA versus 178°, measured again with Kinovea. With this method, we could reduce 10° of the systematic error to a minimum of 1°. This example was a pretest, basis for the offset has been investigated with the five probands, described above.

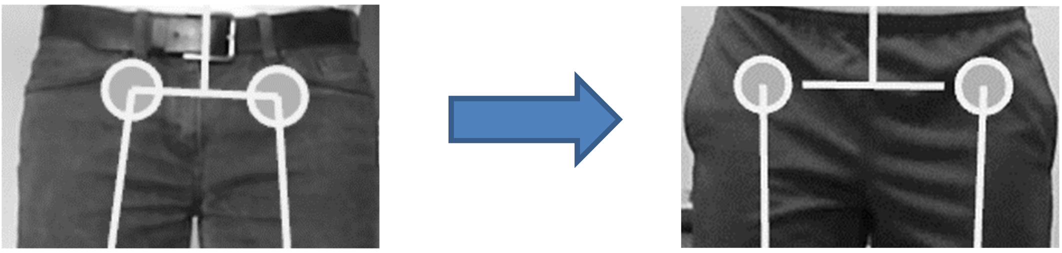

Figure 10: Adjustment of hip points

Authors of studies, that compared the Kinect to marker-based systems also found, that there are systematic errors in the (hip) joint detection of the Kinect system. After modifiying the setting with the Kinect, the measures showed high accuracy compared to a marker-based system [91], [111]. These findings show, that there is a need of correction of the original setting to get the best possible results, when using the Kinect. These findings underpin our procedure, to manually offset the recognised hip points to achieve more realistic HKA calculations in upright standing positions, as well as in motion and maximum ski run positions.

The upcoming text passages cover explanations about Kinect accuracy and the fundament of how the bandwidth has been defined, so that the developed system functions adequately in recognizing and correcting the HKA, but also the knee flexion.

Compared to the gold standard, the Kinect shows less than 10 % of variance in whole-body movements, when playing games with the Kinect [82].

Implementing the Kinect in dynamic knee movements to screen the risks in ACL injury, Kinect shows adequate accuracy compared to the gold standard. But the authors of this investigations claimed, that knee valgus positions could not be detected as accurate as other knee movements [86]. These findings indicate, that knee valgus motions must be corrected very early to avoid that too big valgization occurs and is not notified and corrected by the system. This could in turn lead to increased injury risk, learning incorrect HKA motions and setting inconvenient load to the knee joint.

The fundament for defining the range of motion of the HKA in function is built on three pillars. The first one is the anatomy of the HKA and the resulting physiological leg axis, that ranges from 173°-175° in different sources of literature [65, p. 410], [66, pp. 327–28], [67]. Various studies conclude, that valgization of the knee can lead to damage to the joint and surrounding tissue or injuries [70] [71]. Therapy settings with patients that suffer from knee pain and that show functional valgization of the knee, have a focus on stabilizing the knee along the HKA and strengthening the vastus medialis and gluteus muscles [73, p. 222], [72]. One aim of the developed system is that unphysiological valgization of the knee does not occur while performing a squat or a ski run position in the gameplay. As already mentioned, there is good evidence for increased injury risk, when the knee is in valgus postion in various movements. Due to these findings in literature, we set the allowed valgization of the HKA to zero. That means, that HKA motions are allowed within the physiological knee valgus of 173°, but not smaller.

The second pillar of the mentioned fundament consists of the measurement accuracy of the Kinect and the development tool from Microsoft. There is good evidence in measuring the accuracy. In various studies, measurement accuracy reaches more than 90 % [82] [87], [92], [112], [113]. To define the allowed knee varus position of the algorithm, we calculated with this value of maximum 10 % of variation in recognizing the HKA. Adding 10 % to the average physiological HKA of 174°, we reach a maximum allowed varus position of rounded down 191°.

As there are no such risk factors, moving in this position as in valgus, a wider range of motion to the lateral side can be accepted. Considering again the theory of differentiated learning, a wider range in the movement can lead to positive learning results. The model of differentiated learning makes up the third pillar of the defined HKA fundamentals. As described in the theory part of this work, this kind of learning enables increased fluctuations in movements to improve motor learning and to promote the internal focus while executing motor skills. Fundament of this in sport and therapy approved practice is to improve the motor learning of new movements or on improvements in already known motion sequences.

This gives the user in the field of prevention the possibility to faster and better learn and relearn the correct ski run or squat position [75], [76].

Concluding these three pillars of defining the acceptable range of motion of the HKA of the game, a mix of arguments build the fundament of the chosen settings. As there is sufficient and good quality literature for valgization and its prevention and therapy recommendation, the minimum allowed knee valgus position is zero. That means, that in the frontal plane, no movement to the medial side is allowed from the lowest acceptable physiological valgization of 173°. From the technical point of view, a 90 % accuracy means that even on this recognised knee position, there is still a chance of being even in a more medial position. Considering this fact, there is still enough potential range of motion left for the approach of diffetentiated learning. For these mentioned reasons, there is no allowed valgization accept the physiological one. Concluding these well-founded considerations, the game HKA bandwidth ranges from 173° to 191°.

To define the bandwidth of knee flexion, muscle activation in various flexion angles, as well as considerations about optimal loading of the knee joint have been undertaken.

Recent investigations on the muscle activity of young, healthy individuals without any pain showed significant higher muscle activity of various parts of the quadriceps muscle in 60° of flexion, compared to 15° of flexion [79]. In 90° knee flexion, isometric holded squat, the highest activation of thigh muscles and gluteus muscles has been measured. At 140° knee flexion, there is a decrease of the mentioned muscle groups. At 20° of flexion, there is significantly more muscle activation of the vastus lateralis muscle detectable compared to 140° flexion [114].

Due to these findings, a squat position without extra weight, like in the game, in the range of 20-90° of flexion demands high activation in all big muscle groups of the lower extremity. Additionally, a parallel squat as demanded in the gameplay of i4Ski is verifiably not unhealthy in a range from 0-100° of knee flexion, when practiced by healthy individuals [78]. For these reasons, the valid knee flexion range has been defined from 20 to 140°.

4.1.4 Gamplay i4Ski

In this chapter, the gameplay of i4Ski is presented. When starting this prototype exergame on the computer, an introduction video starts and provides explanations of how to play the game (Figure 11).

Figure 11: Introduction of i4Ski

After the intro, the tracked users can see themselves on the screen. This is the calibration mode, in which the most important tracking data are displayed (Figure 12). The user now has to find the correct tracking position, which is important for an adequate function of the Kinect sensor. When the standing position is correct and the user elevates the left arm, a countdown starts the skiing game.

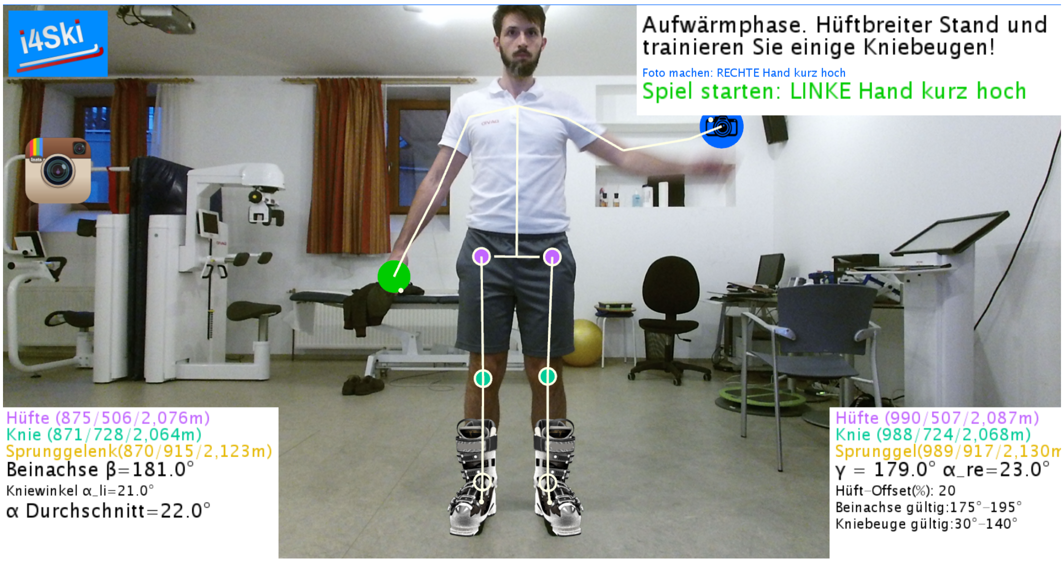

Figure 12: Calibration mode of i4Ski

The objective of the game is to reach as much score points as possible. This can be achieved, when the HKA is in the allowed bandwidth and the knee flexion is not to small or to high (see also specifications in chapter 4.1.3. Adjustments). The more knee flexion and in turn the more schuss position is implemented, the faster the score is counting upwards. This should motivate the user to firstly keep the correct HKA position and secondly, to do as much knee flexion as possible and allowed. This is not just to fully activate the muscles of the lower extremity, but also to create a realistic setting in which the users can place themselves into a real ski run and empathise with real skiers.

Figure 13: Ski run of i4Ski

These games characteristics should motivate the user to exercise correctly and to improve the endurance.

As the game is developed and tested as prototype, users can not start the game by themselves. Instead, the tester starts the game as part of the testing phase, which is described in detail in chapter 5 (Reseach methodology).

At the end of the ski run, the user can make a photo of themselves by holding up their right arm. Then, a screenshot is taken and a symbol of a trophy is displayed on the right hand. For a second run, the user must hold up the left arm.

5 Research Methodology

In this chapter, a description about implemented methods, usability questionnaire and the implementation of the laboratory tests is delivered.

5.1 Main research question

The aim of the evaluation was to investigate, wether the developed prototype is usable in the therapeutical, preventive and health promotive setting. To define usable, standardized measures have been chosen to calculate usability data, that can be compared to existing literature. Therefore, the main research question for this study has been formulated as: **What is the grade of usability of i4Ski?**

The definition of usability and recent insights are delivered in chapter 5.3 Usability. According to the stated research question, the following hypotheses have been written down in table 3. These hypotheses must be verified within this study (see also 6 Results).

	Hypotheses
H1_0	i4Ski does not show an acceptable grade of usability for preventive purposes and health promotion.
H1_1	i4Ski shows an acceptable grade of usability for preventive purposes and health promotion.

Table 3: Research hypotheses

5.2 Research method

5.2.1 Participants

As described in chapter 5.2.2 Questionnaire, the evaluating experts and study participants have been defined as physiotherapists and physiotherapy students at least 5th semester as well as sport scientists and sport scientist students at least 5th semester. No further selection process has been carried out for the recruitment of the participants.

They have been chosen by disposability, since the number of available physiotherapists and sport scientists as well as nearly graduated students in these two fields is constrained considering the chosen locations for implementation and the limited time slot. There were no limitations regarding age, working experience or knowledge in digital media or information technology.

5.2.2 Questionnaire

To investigate the usability of the developed system, an online questionnaire has been designed. As questionnaire tool “unipark” has been used to prepare the questions for the probands. With this quantitative research approach, results that have a high comparability can be produced.

The questionnaire contains three main elements. These are: demographic data, usabilty statements, expert evaluation questions. The full survey in paper form is attached at the appendix. Statements to evaluate the usability are standardized from the SUS by Jeff Sauro. This “quick and dirty” scale has been used in 1986 for the first time for a computer application. Bangor et al (2009) conclude, that the SUS has good validity and reliability and can be used as an international standard measuring tool [115]. It uses a Likert-Scale with five characteristic values. “1” = “strongly disagree”, “5” = “strongly agree” (Tab. 4). The values between are gradations between these two extremes [116].

Strongly Disagree 1	**Disagree 2**	**Undecided 3**	**Agree 4**	**Strongly Agree 5**
○	○	○	○	○

Table 4: Likert scale, based on Bowling [117]

The Likert scale is a common rating scale. With five characters, it offers more than a yes or no decision, as well as the option of staying undecided or without opinion [118]. Compared to scales, which have an even number of characters, the Likert scale has a neutral button. This could potentially lead to the fact, that participants of the questionnaire do not clearly decide if they agree or disagree with a given statement. Instead, they choose the neutral button and the evaluation of the statement could be inconclusive. Scales with even number of characters force the participant to come to a decision. Nevertheless, I chose the Likert scale because it is a popular tool in questionnaires and the SUS also included it as a standard measuring tool. Although the tendency towards the centre is present, the possibility to stay undecided or to leave a statement unrated is also beneficial.

In the table below (Tab. 5), the translated statements of the SUS are listed. The German version is presented because only German language native speakers have been tested and asked to join the survey.

ID	Statement
SUS1	Ich denke, dass ich das System gerne häufig benutzen würde.
SUS2	Ich fand das System unnötig komplex.
SUS3	Ich fand das System einfach zu benutzen.
SUS4	Ich glaube, ich würde die Hilfe einer technisch versierten Person benötigen, um das System benutzen zu können.
SUS5	Ich fand, die verschiedenen Funktionen in diesem System waren gut integriert.
SUS6	Ich denke, das System enthielt zu viele Inkonsistenzen.
SUS7	Ich kann mir vorstellen, dass die meisten Menschen den Umgang mit diesem System sehr schnell lernen.
SUS8	Ich fand das System sehr umständlich zu nutzen.
SUS9	Ich fühlte mich bei der Benutzung des Systems sehr sicher.
SUS10	Ich musste eine Menge lernen, bevor ich anfangen konnte das System zu verwenden.

Table 5: SUS statements in German [116]

The third part of the questionnaire compounds from self created statements that aims to evaluate the opinion of the tested health care experts. They have not been proved for validity or reliability, but they can deliver important feedback that can help to improve the system from the medical and technical point of view. Due to this, no score or significance can be calculated statistically, but the rating of the statements can show tendencies from the sight of motion experts. As on statements from SUS, for these statements the Likert scale with five characteristic values has been utilized. These self created statements are delivered below (Tab. 6).

ID	Statement
EVA1	Das System erfasst die Beinachse ausreichend genau für ein präventives Training.
EVA2	Ich kann das System für ein präventives Beinachsentraining weiterempfehlen.
EVA3	Das System eignet sich zur allgemeinen Gesundheitsförderung.
EVA4	Das System zeigt eine adäquate Fehlermeldung bei zu großer Abweichung der Beinachse an.
EVA5	Ich würde das System im Rahmen der Gesundheitsförderung zum Einsatz bringen.

Table 6: Expert evaluation statements

The last part of the questionnaire is an empty input field, where participants were able to leave feedback to the tested system. This field was no obligatory part of the survey.

For this expert evaluation, an important feedback about the entity of the tested sytem in the medical context is necessary. In this case, physiotherapists and sport scientists including students of these professions that have passed minimum the 5th semester are defined as experts. They are certificated health professionals and experts for movement development and control. The physiotherapeutical job profile includes the prevention and preservation of dysfunctions of the locomotor system [119]. Sport scientists and students in the 5th or higher semester are experts in sports and movement sciences. Their area of concern is the human motion, especially athletic motion and the self-conception of motion [120].

For this reason, the expertise of the mentioned probands is crucial in the medical evaluation phase of this prototype system.

No technical evaluation was planned or has taken place in this paper. The main issue was to get a better understanding of the medical background and possible applicability in the medical environment and the field of prevention and health promotion.

To survey possible missinterpretations or uncertainties in the questionnaire, a beta test with five persons has been executed in the survey prepatation phase. These persons have been chosen randomly at the library of FH St. Pölten and had no knowledge or relation to this work.

They went through the statements given above and gave verbal feedback after finishing. The feedback has been summarised and listed below (Tab. 7). To keep the procedure simple, no further information from these anonymous persons has been documented.

	Statements in German language	**Solution**
# 1	Ich kann mir unter dem Begriff „Inkonsistenzen“ nichts vorstellen.	The term has been explained below the statement (SUS6).
# 2	Was soll ich auswählen, wenn ich unentschlossen bin?	An explanation about the value of the scale has been added. Probands choose „3“, if they cannot respond to an item.
# 3	Müssen alle Fragen beantwortet werden?	All statements are defined as mandatory fields. The survey program will query, if not all statements have been rated.

Table 7: Feedback on beta test of questionnaire

5.2.3 Implementation

The implementation has been held in two locations with standardised conditions. One test location was the digital health lab of the FH St. Pölten, the second location was the medical diagnosis room at David Gesundheitszentrum Krems. Special attention has been put on the standardised test conditions.

The utilised hardware has been described in chapter 2.4.1 Hardware. The setting has been chosen in a way, that produces an optimal incidence of light. This is important for a good functionality of the Kinect sensor. Standardised conditions are shown in the table below (Tab. 8):

Hardware	**Measures**
Screen	Hight: 120 cm, centered to the calibration position
Kinect	Distance to calibration position: 200 cm Hight: 74 cm Position: neutral position (no incliniation up or down), centered in relation to the screen

Table 8: Standardized testing conditions

After each proband has been welcomed to the test laboratory, a verbal explanation about the test procedure and the aim of the test was given by the test coordinator, which in this case was the author of this study. After this, the test situation was prepared and the test object started [14, p. 139].

During implementation, only one proband was present in the laboratory, to avoid that other probands influence each other or have more time on watching other game rounds, which could lead to a biased impression that is different to other probands.

Following verbal, self-written explanation originally has been given to each proband: “Willkommen. Dieses zu testende Kinect-basierte Spiel soll im präventiven und gesundheitsförderlichen Bereich im Rahmen einer Physiotherapie Einsatz finden. Um mögliche Schwächen des System zu evaluieren, wird eine ExpertInnenevaluation und ein Test der Gebrauchstauglichkeit vorgenommen. Es wird eine Skiabfahrtsähnliche Simulation gestartet, bei welcher die Beinachse erkannt und bei Fehlstellungen eine Korrektur angezeigt wird. Zu Beginn bitte genau hinter die Bodenmarkierung stellen und auf die Kalibrierung durch das System warten. Danach den Anweisungen des Programms Folge leisten und das Spiel einmal durchspielen. Im Anschluss wird mittels eines Fragebogens deine Einschätzung zu dem gestesteten System abgefragt. Wir starten - bitte Position einnehmen.”

The probands had to accomplish two rounds of the game. The main reason for this procedure was, that one run of the game is too short to capture nearly all impressions of the gameplay. With the second try, the proband can discover most functionalities in the game and can better understand its functions. After thr practical testing, the probands were asked to fill out the online questionnaire.

5.3 Usability

“Every application has an inherent amount of irreducible complexity. The only question is who will have to deal with it, the user or the developer.” *Larry Tesler*

The aim of evaluating the usability of the developed Kinect-based system is to identify deficiencies of the system from health care experts. On the one hand, operational blindness can be prevented through a view from the outside of the development work [14, pp. 134–35]. On the other hand, motion experts are predestined to feedback a technology that promises to correctly recognise human movements and correct wrong movements or joint positions.

Usability is described as the extent or capability to which a product or application can be used by specified users to achieve specified goals with efficiency, effectiveness and satisfaction in a specified context of use. [101]

John Brooke (2013) described „that usability in any given instance is defined by the context of the use of a system, it follows that in general, the way in which you measure usability will also necessarily be defined by that context. ISO 9241- 11 breaks the measurement of usability down into three separate components that must be defined relative to the context of use:

• Effectiveness (whether people can actually complete their tasks and achieve their goals)

• Efficiency (the extent to which they expend resource in achieving their goals)

• Satisfaction (the level of comfort they experience in achieving those goals)

Thus a system that lets people complete their tasks, but at the expense of considerable expenditure of time and effort and which was felt to be very unsatisfactory by all concerned, could not really be said to be usable.” [121]

5.3.1 Usability versus User experience

Besides efficiency, effectiveness, context of use, also satisfaction is investigated when mentioning the term usability, compared to user experience. User experience concentrates more detailed on individual preferences, sensory perception and emotions while the usage. There are also approaches from psychology and emotion research [14, p. 13].

5.3.2 Methods

A common method in evaluation as usability test is a so-called participatory observation. A main part of this test is task-based. The proband is prompted to perform a specific test task to evaluate weaknesses of the tested subject. After this process, an interview or evaluation questionnaire can be held to inquire data and assessment from the proband [14, pp. 134–37]. Grünwied recommends a minimum of 5 probands for a usability test, commonly there are 8-12 probands. In this final stage of development or rather at the end of this process, usability tests should point out weaknesses of the programme. The author suggests a preparation for the usability test.

- Why? Defining the aims of the test. What kind of result is expectable?
- Who? Describes the user or experts who will test the product.

- What? Defining the test object.
- How? What is the task in the test?
- Whereby? Techniques for the test situation are defined, e.g. score counting through motion tracking.
- Which questioning? Interview or questionnaire?

Finally, a time schedule for the test should be developed to guarantee a clear and standardized test procedure [14, pp. 134–53].

Albert and Tullis (2013) suggest for formative usability laboratory tests small numbers of probands. On laboratory tests with the aim of capturing a combination of quantitative and qualitative data, a number of 12 or more probands is suggested. In the phases of research, design and implementation experts in the particular field should inspect and evaluate a product. These steps are all before the release. With approximately 10 probands, user tests and interviews can be implemented from the end of the research phase to or over the release, into the analyse phase. More than 10 probands are required for questionnaires and usage during implementation phase, throughout the release and even during analysis [122, pp. 41–62]. The aim of the implementation phase was to generate as much probands as possible, because the test procedure is simple and easy to implement. Due to given literature and the limited time, 20 persons has been asked to join the tests. Finally, 10 probands implemented the practical tests.

In this work, as mentioned earlier, the proband is defined as mixture between expert and user. That is because the physiotherapists or sport scientists are motion expert and so they are predestined to do evaluation in this field. On the other hand, they are user at the same time. The present prototype is not yet a stand-alone, that can be used by everone for prevention and health promotion. It is developed for the use in a therapeutical setting, steadily under therapeutical supervision. A possible setting could look like the following:

A client joins a knee prevention programme in a physiotherapy practice. In the first session, the physiotherapist does anamesis and examiniation. After this, the prevention programme is being executed. Under instruction the client does a warm up. Then she or he gets information and advice how to correctly stand and walk and how to optimally load the joints of the HKA. As a therapeutic method, the therapist demonstrates an optimal movement or position, so that the client can better understand the matter and can learn by watching the optimal state. As the physiotherapist is continually in further studies and tries to be state of the art to deliver the best possible service to his clients and patients, he also uses digital and media technology in his practice.

In this hypothetical case, the therapist uses the i4ski as a part of his therapy session. At first the system is getting explained. Then, the therapist demonstrates an optimal parallel squat, as it is required in the game, in front of the Kinect. The client can again benefit from learning by watching. The displayed information from the game underpin the given information from the therapist. After this, it is the clients turn to play the game and execute the correct and optimal HKA position, as required in the game.

This short explanation shows, that the therapist can also be defined as user, because she or he uses the system to teach and demonstrate correct movement patterns.

A systematic review on usability evaluation methods found no existing standardization in evaluation methods. The authors concluded, that the investigated usability studies used different analysis variables. The evaluation in the investigated studies has been done with experts or users, using quantitative and/or qualitative methods. There is a lack of methods and studies which leads to a lack of standardization [123].

For the implementation of a usability evaluation, guidelines for three stages are recommended. In the pretest stage, considerations about the used methods should be made. A questionnaire which tracks physical and cognitive aspects is suggested [123]. In this study, a questionnaire has been chosen as quantitative instrument.

The second stage of the guideline – during the implementation, authors suggest the collecting of performance and physiciologial data [123]. The skiing game tracks the testers´ motion data and calculates a score, depending on the performance of the tester. Tracking physiological data like the heart rate have been considered, but rejected because of the amount of effort in tracking the data and rather in evaluation it in combination with the exact timeframe of the motion data and the physiological data.

In the posttest, the choice between qualitative and quantitative analysis must be made. In a quantitative approach, the use of TAM or SUS and a Likert scale, which allows statistical analysis, are suggested [123]. In the present study, the questionnare consists of a standardized usability questionnaire – the SUS, and an expert evaluation as mixed method. The scale is a five characteristic Likert scale.

Considering the four types of methods for usability evaluation by Preece (1993), the present study uses all methods for its investigation. These are listed in the table below: (Tab. 9):

Original context	Actual use in study
Heuristic evaluation or experts-based evaluation	Experts evaluate the system and describe problems
Observation	Motion data tracking
Surveys	Questionnaire
Experimental evaluation	Mixed method – usability questionnaire and expert evaluation plus feedback

Table 9: Types of usability methods, based on Moumane et al (2016) [124]

The methods above have been implemented through laboratory tests. "In a laboratory experiment, users must perform tasks relating to a mobile application in a very specific and controlled environment, away from interruptions, noise, etc. Hence, the control of the experiment and data collection is not an issue, but it is nonetheless unrealistic." [124]

Grünwied (2017) describes various methods to do evaluation with new (IT) products, launches or re-launches. A certain additional benefit lies in the use of mixed usability methods. An example of a possible path is shown below (Tab. 10) when the aim is to create an innovative (IT) product [14].

Method	User- and usage investigation	Layout	Evaluation
User diary	X		X
Persona	X		
Use cases	X		
Who-does-what-matrix		X	
Prototyping		X	
Usability-Test (out-of-the-box-test)			X
Questionnaire (Evaluation)			X

Table 10: Mixed method, example ‚innovative product', based on Grünwied (2017) [14]

As the user- and usage investigation is not part of the present work, no attention has been payed to the according methods. In the field of layout, the main focus has been set on the prototyping, because that was the main cooperation with the student from digital media, who did the main part of programming the algorithm. For this reason, the Who-does-what-matrix was not relevant anymore in the stage of development. Grünwied declard, that usability tests within the evaluation phase is indispensable. Questioning about subjective opinions and expert evaluation deliver additional, valuable information about the product [14].

To do a delimination of the testing area, this investigation only includes the usability and expert evaluation for preventive and health promotive purposes. There is no investigation and evaluation of the following: Design, functionality, controls, technical details, gaming experience or user experience.

5.3.3 Interpreting Scores

To interpret the SUS score, a standardized calculation must be made. The scores of the rated statements of each proband is summed up and multiplied by 2,5. The result is not a percentage, but the SUS score, that lies between zero and 100, which is the highest reachable score. As mentioned, the average score is 68 [121].

6 Results

In this part of the paper, results from the questionnaire are presented. To better understand the meaning of analysed data, the findings are described briefly. The full original table of results to each subject of the questionnaire is provided in the appendix.

Analysis of the demographic data shows a balanced ratio of five female and five male participants. The age distribution (Fig. 14) shows, that nine from ten participants are aged between 20 and 39. Considering, that the earliest possible career start, due to the necessary education, lies in the mid twenties, it can be deduced, that most participants (9/10) do only have a few years of working experience in their field.

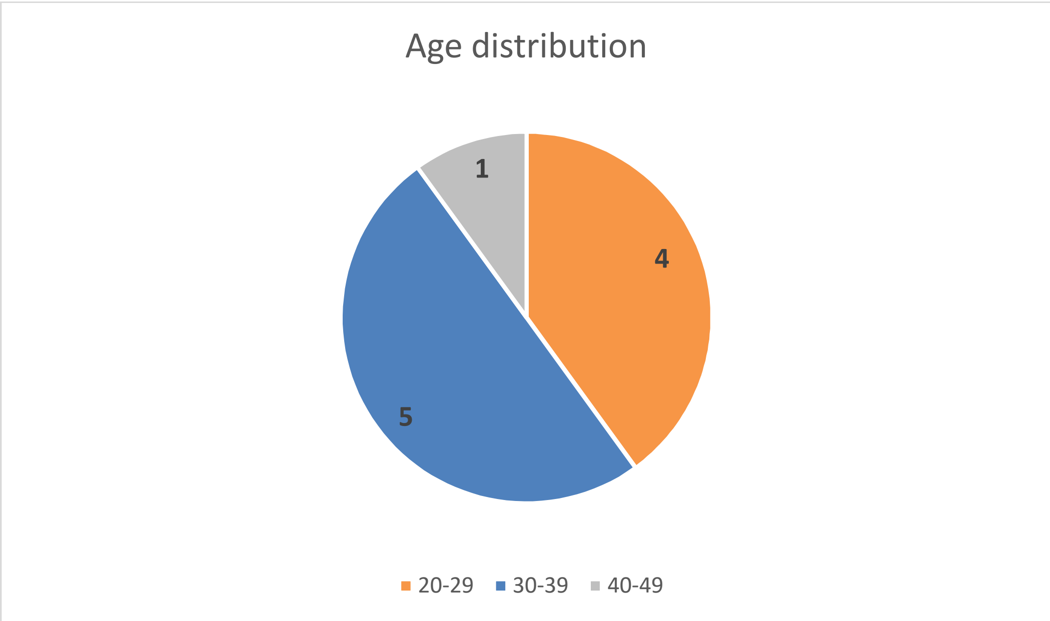

Figure 14: Age distribution

To analyse data of the usability statements, the mean SUS values of all participants has been summed up to the total SUS score, which is represented in figure 15. To calculate the score for each participant, a standardized SUS calculation has been used.

Values from questions, that are phrased positively, so that an agreement with the statement is rated with 5, get an abstract of the value 1. Converesely, the values from statements, that are phrased negatively, are abstracted from the value 5.

Consequentely, this procedure happens 5 times for each type of statement, in sum 10 times. These ten values are then summed up and multiplied with the factor 2,5. This results in the participants individual SUS score. The summed-up score of all participants is **81,3**.

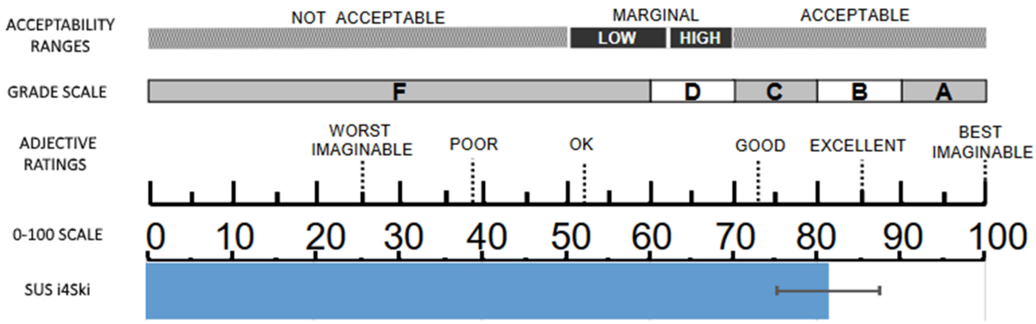

Figure 15: SUS i4Ski compared to other scales, modified after Brooke (2013) [121]

As shown above, the SUS of i4Ski is compared to various score methods to better interpret the score and its meaning. Including the 95 % confidence interval of 6,08 a range of 75,22 and 87,38 is given. Even with the lowest range of a score of 75,22, the SUS of i4Ski is still above average of 68 and at an acceptable level of over 70. Classified in classic school grade scales, i4Ski grades at B. Brooke added adjective rateings to better compare the SUS score with each other. The prototype i4Ski lies between the adjectives "good" and "excellent" [121].

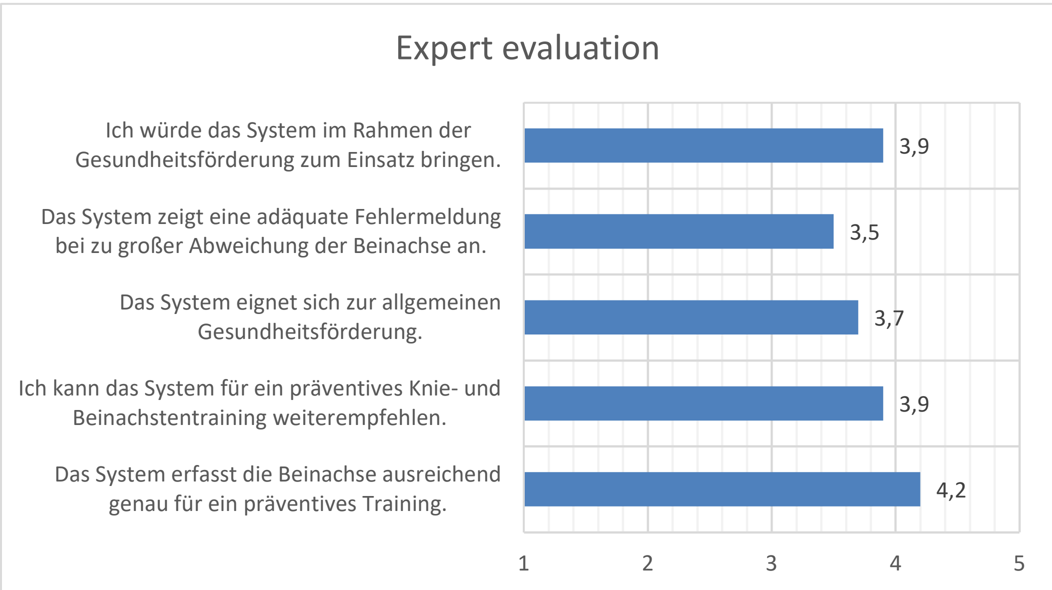

Figure 16: Results of expert evaluation

The next part of the questionnaire was the expert evaluation. The analysed data are presented above (Fig. 16). As mentioned in the chapter research, these statements are not standardized, but self written.

Adjusted to the individual prototype exergame, it aims to evaluate weaknesses of the HKA recognision and the probability that the programme is recommended for prevention and health care purposes.

Finally, these statements may report tendency for the programmes suitability and the validity of the HKA recognision. As rating scale, again the Likert scale has been used. That means again, that “1” equals absolute disagreement, “5” equals absolute agreement with the given statement, “3” means a neutral rating.

All statements have been rated with a slight agreement. Highest agreement showed the fifth statement, that says, that the system captures the HKA sufficiently accurate for preventive trainings. Lowest agreement with a value of 3.5 reached the sentence that stated, that the system shows an adequate error message when the HKA deviates too much. Due to missing references, clear interpretations and recommendations can not be derived from this part of the questionnaire, but it gives a good overview of the expectations and requirements, that health professionals have towards digital technologies in the healthcare use.

The final part of the questionnaire, the written feedback of the participants is summarized below and can be found in original length and language in the appendix.

Participants claimed, that the gameplay is to static, they would like to have more variance in movements as dynamic reactions in the game. The game feedback should better be given visual, instead of written words on the top. Generelly, a better design has been recommended to better focus on the ski run, as on various parameters and tracking information. To improve the feedback on HKA errors, a different type of feedback is recommended, for example auditive feedback or superimposed arrows that point on the HKA error. Some participants recommend a revision and redesign of the programme before implementing it into the practice.

On the positive side, participants mentioned, that the game is motivating and funny. The HKA has been captured adequately, but the feedback of an incorrect HKA could be implemented more structured.

In Table 11, the deducation of the presented findings is shown. It can be concluded, that the hypothesis H1_1 can be confirmed. i4Ski has been shown at least an acceptable grade of usability. Even more, compared to different sources of literature, the reached SUS score of i4Ski can be rated as at least “good” [121], grade “B” or the top 10% of 5000 recorded surveys [116].

	Hypotheses	**Result**
H1_0	i4Ski does not show an acceptable grade of usability for preventive purposes and health promotion.	**Rejected**
H1_1	i4Ski shows an acceptable grade of usability for preventive purposes and health promotion.	**Confirmed**

Table 11: Rejected and confirmed hypotheses

7 Discussion

After presenting the findings of this investigation, further results and their consequences and general limitations are discussed in the following section.

7.1 Results

At first an overview of negative written down feedback of the questionnaire is presented in table 12. These valuable data can be used to further develop the prototype – appropriate recommendations, deduced from the feedback is summarized and shown in the table below. Most of the feedback was given constructively, so that most of it can be pulled up seriously for a redevelopment process to improve the gameplay.

Summarized negative feedback from participants	**Possible adaptations and adjusments of i4Ski**
Error messages not perceptible adequately; visual instead of written error messages	Displaying the error messages into the ski run in the form of arrows nearby the knee joints
Too many elements on the screen; too much concentration in the tracking model instead of the ski run video	Removing detailed data of tracking, instead the ski run is presented bigger; presenting tracking details at the end
Game duration too short, more ski runs too choose from	Adopting more and longer ski run videos, with the option of interrupting the run with a hand signal for those who are at a lower level.
Game too static	Integrating ski jumps in the form of real double-sided jumps
More stimulus to train harder	More sources of feedback, longer ski runs
Better explanation of the game functions	Option to see a tutorial or remaking the introduction video including a better explanation of the game functions.

Control ski turns with hip movements	Not feasible in this concept, because the game is based on a recorded ski run, which is not modifiable this way
HKA is not tracked accurate all the time	Recommending better training conditions, so that the tracking works under best possible conditions, including sufficient light, uncovered knee joints (sporting shorts)
Missing distractions and variety in the game	Integrating more game variations like different ski runs or difficulties in the gameplay (for example: jumps)

Table 12: Written-down feedback and possible adjustments in the gamplay

Having a closer look at the summed SUS, an analysis of the participants' individual SUS may give deeper insights. In the following graph (Fig. 17), I changed the scaling, beginning with 70, the acceptable minimum for SUS scores. One participant rated the game below this score (65) in is therefore not visible in the figure with this scaling. Three participants are close above this line. The highest rating was a SUS of 97,5, which is near the adjective "best imaginable" from Figure 15. The average SUS of all participants is 81,3. This value is displayed as the orange horizontal line that crosses through the bars of the chart. The value of 'p2', which bar is not shown here, is included obviously.

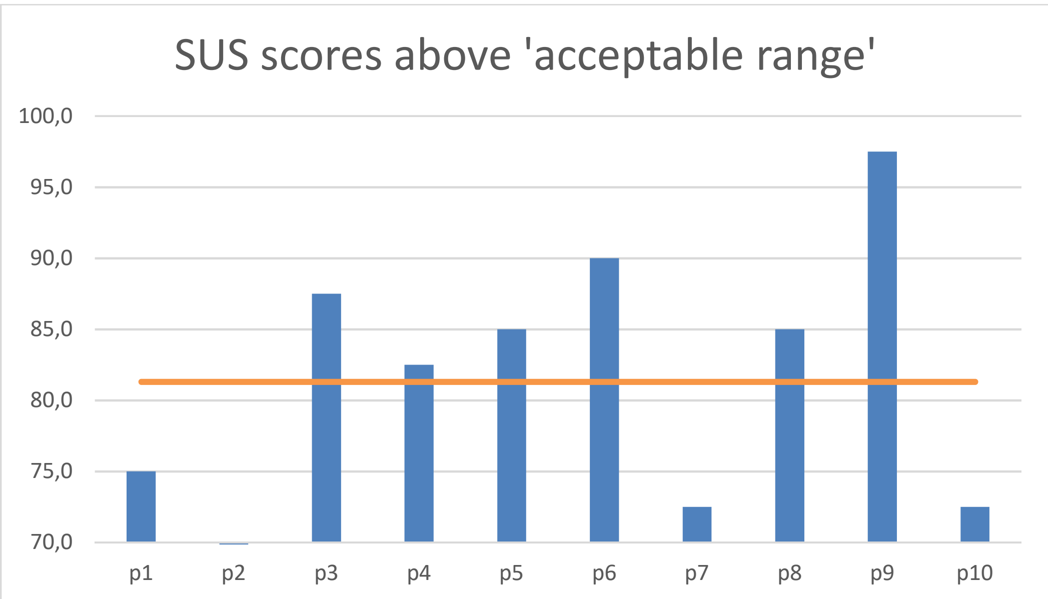

Figure 17: Individual SU scores

Comparing results from the SUS and from the expert evaluation, it is noticeable, that the outcome and conclusion is not quite the same. While findings from the generated SUS suggest not less than good usability and therefore a soon possible implementation, findings from the expert evaluation show, that there is still a need of redeveloping the prototype before it comes to an implementation in the medical practice. Although participants barely agreed the statement that aims a recommendation for prevention and public health, this result is too undecided to express a clear recommendation. Interesstingly, statements concerning the HKA showed the biggest difference in the rating. While there is the highest rating of the statement regarding the adequate recognision of the HKA, participants do not clearly agree with the statement that refers to the adequate error message of a wrong HKA (see also figure 13).

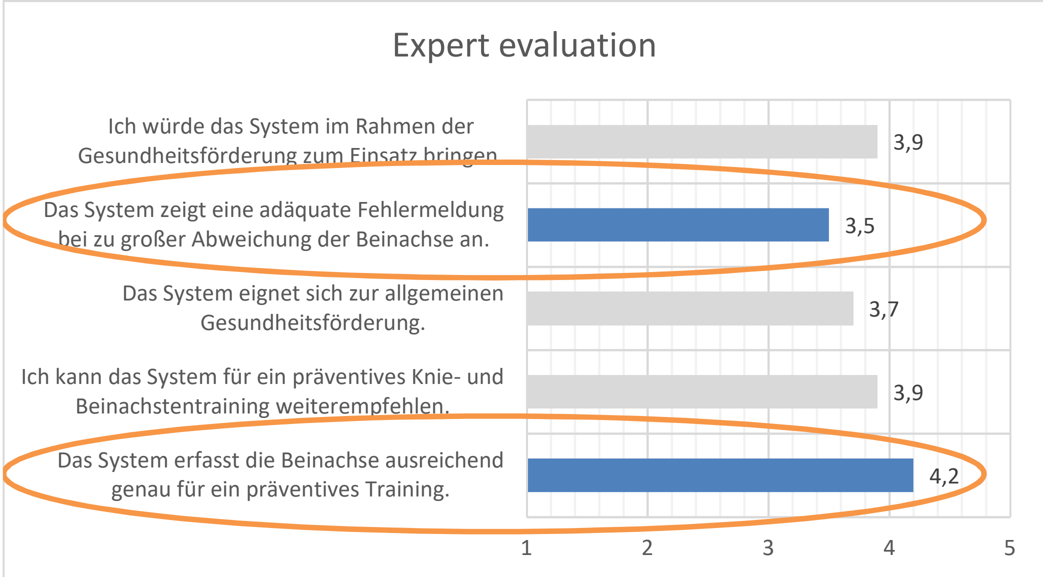

Figure 18: Expert evaluation; statements about HKA

It may be discussed, why on the one hand participants state a good up to excellent usability, but on the other hand, a clear recommendation for the practical use in health promotion and prevention can not be given. This is even more surprising, as the game is only declared for the use without patients, but with healthy individuals and only in supervision of a therapist. One reason may lie in the kind of questioning and the different aims of the questionnaire parts. While the statements of the SUS are more general, the statements of the expert evaluation ask for more specific concerns about the game and ask for clear recommendations. Users may be familiar with the gameplay and can use or handle the game easily, but they set strict standards when it comes to the clients or patient safety. This hypothesis would underpin the integrity and professionalism of the tested persons.

Another explanation for the discussed discprepancy may be answered with the written-down feedback that gives a deeper insight in the participants needs and shows their free opinion.

7.2 Method

Having two testing locations is very advantageous to reach more potential participants, but the consequence is that the setting is not exactly the same. Although I tried to adjust the hardware as accurate as possible, different light sources and an unchangeable room background at both places do probably produce different results in the tracking.

Another good aspect of the applied test implementation was the accurate setting we adjusted. Combined with the calibration mode of the game, it was easy for the participants to correctly position in front of the sensor.

It may be considered, if two Kinect sensors could bring more accuracy and therefore a higher SUS and higher recommendations ratings. An investigation which compared the gold standard with a system that did motion tracking with two sensors found out, that the results are similar [84]. The costs would only be slightly higher, but the performance may be significantly better. In a setting, were the sensors are built-in permanently, this would also make no extra effort.

7.3 Limitations

As the probands of the implementation have been chosen from the researchers' social and work environment – colleagues and fellow students, the results may be influenced by bias. Considering that the probands knew the co-developer of the system and his intentions and the underlying motivation, they might be inclined to submit a positively skewed evaluation.

As most of the participants tested the system before or after work, they were wearing long dark sweatpants, which is one of the most disadvantageous clothes to wear, when getting tracked by a markerless sensor system. As already mentioned, the incidence of light may lead to different tracking results too. This was the case, because of different testing locations and different testing times – from the morning with sun, until the night with artificial light sources.

8 Conclusion

This study presents the process of co-developing and evaluating an exergame in the field of prevention and health promotion. A student cooperation has been started to further develop an existing skigame by Martina Strohmayer. The main common objective was to further develop the prototype so that reliable accuracy measurements and usability evaluations can be implemented with this system. The time frame has been chosen generous to have some time buffer in case of unexpected delays. The development phase was planned to be finished until March, so that the implementation, test phase and evaluation of data can be done from April to May. Actual, we had a delay of about 4-5 weeks before I could start the practical tests, because of a massive work load in the development and accuracy measurements. It finally took us a lot more time to do a good adjustment of the HKA, which varied a lot in motion. The test phase ran well and quickly. The system ran without any interruptions and did deliver reliable tracking data most of the time. As described in the discussion, the joint tracking of the knee joint caused some minor troubles, because of the long dark clothes of the participants. After the practical part, participants had to take part on the questionnaire. This method showed good reliability and the response rate was 100 %, due to some reminders the particpipants received. The results are a SUS score of 81.3 and an expert evaluation, which can not be summarized into one figure. Although the expert evaluation is no valid and reliable tool, it came to light that there is the need of subsequent improvements of the prototype. While the SUS shows “good” to “excellent” results, compared to existing profound literature, the conclusion of the expert evaluation is that a clear recommendation for purposes of prevention and health promotion can not be given at this point, but the detection of the HKA is sufficient from the experts’ perspective.

The hypothesis H1_0 can be rejected. The main research question “**i4Ski shows an acceptable grade of usability for preventive purposes and health promotion”** can be confirmed.

Because of this ambivalent finding, the development circle of this prototype should be started again to eradicate errors and weaknesses of the system. The feedback of the participants should be the main guide to adjust the system. Possbile adaptation and adjusments, that are listed in table 11, could be the first immediate stepts for improvement.

Although we have proven, that a self-developed exergame can be usable and quite reliable, I can not recommend a usage outside the therapeutical setting at this point. Firstly, technical progress should not and can not replace physiotherapists with their profound expertise and empathy for humans. Secondly, from my point of view these systems like the one in this study do not track every motion, for example small hip rotations or pelvic tilts, as accurate as must be, to do a serious and healthy training. That is even more important, when it comes to possible implementations with patients. This system does not provide a holistic picture of the individual, but good tracking results on single joints or the HKA. This technology is very useful and modern support in therapy and extension of therapy settings. Therse is a definite added value, when using this technology in prevention or health promotion. But I can not declare the use in homes or without health professionals at this point.

The chosen mixed method to do the evaluation was a good choice. With this method, a holistic picture could be gained. If I only queried statements of the SUS, I would now conclude, that the system can be used from now in the medical practice, because of the good SUS ratings. Sometime only small things are important, that the (co-)developer does not see because of an operational blindness. But, with more and detailed information, a redevelopment cycle can be started and valuable written-down information from the participants can be directly implemented into a new version.

Surprisingly, the written down feedback from the participants was very constructive and valuable. Most of improvement suggestions can be implemented quite easy and may yield an even better SUS score. Without that special response, we would probably not have discovered these deficiencies. Generally, the used mixed method brought a lot of advantages in the evaluation of the prototype. With all these data, a more holistic picture can be drawn, to better understand what this system needs to be improved and to get integrated into the health care system.

There could be an extension in the measurement. As some of the participants told me, that the ski run is quite exhausting, it may be useful to implement an BORG scale (RPE). This meaningful and reliable assessment tool measures the grade of physical exertion and is rated from 6-20 [125]. With this data, a better assessment of the users' perception can be gained and a better estimate of which level of difficulty should be chosen. Furthermore, it delivers an additional safety tool, to detect cardiac or other insufficiencies. Considering the fields of applications, a redeveloped programme could also be implemented for cardiovascular rehabilitation with only limited loading capacity.

Conlcuding the development work, findings from the questionnaire and the lack of evidence, stated in theoretical part, i4Ski provides a good and useful preventive training. A self-developed and adjusted HKA bandwidth has been successfully implemented in the game and it works well. In general, the presented system runs stable, is easy to start/run and delivers valuable and accurate tracking data. The good usability results show, that the game is usable in practice. All parameters of the expert evaluation showed slight consent, which again confirms our hard work on developing this game. The only small downer is, that the consent is not more explicit. On the other side, received feedback is mainly positive and very helpful for further development and adjustments of the game.

To sum up, this work delivers good evidence for usability of a self-developed exergame in prevention and health promotion. It turned out that the utilized mixed-mehtod approach was an excellent choice to generate valuable data and to optimally do interpretations about the developed prototype. Finally, this game may contribute a portion among other digital technologies to generate substantial and sustainable savings in healthcare. When it finally comes to an implementation in standard healthcare, it has the potential not just to bring savings, but to generate an added value to individuals. Listing all the advantages, the human component in this story must be considered. Although new digital technologies provide various benefits, the social impact in training and therapy shall not be forgotten. In future, we may benefit a lot from digitization and the use of smart technology, but these shall not replace humans in the interaction with other humans, which is essential, but provide an added value and disburden our social and health systems.

8.1 Outlook

After redeveloping the system, a retest of usability and expert evaluation may be started. If results are acceptable, the system may be tested in the medical practice, for example on healthy individuals for prevention and health promotion. A sensible location would be a rehabiitation center or self-employed physiotherapy practises. The users may again be asked for their opinion in form of a questionniare to raise valuable data for improving the system. Another thing that should be done is the application on patients with knee complaints. This may occur in form of a controlled study. Finally, the game may also be used on patients, that suffered from a ski accident and who want to go back in skies again, but do not have the physical as well as mental constituion yet. In all these scenarios, the game should be implemented in the therapeutical setting.

Rethinking the feedback and a realistic gameplay, more feedback input may be delivered to the user. Although our considerations about feedback in development phase were, to not overload the user with information, it may be wise to better organize the amount of feedback, but to use more sources. All in all, the amount of feedback may be reduced, but better split up into various kinds of origins. There may be acoustic feedback, that motivates the user when the HKA is good and many points are collected in the game.

As already mentioned above, the design should be changed, so that the user gets a better overview of the game functions. Another reason for this change is, that the user can better concentrate on the shown ski run video, which is the main component of the game. For this reason, the skeleton consisting of the tracking points of the user, will be removed from the screen. Instead, a detailed analysis of the played ski run will be presented at the end of the run.

Instead of extrinsic feedback only, as planned in the development phase, there may be also given intrinsic feedback, when the user is more advanced. This would be an extension of the integrated theory of differentiated learning, where the intrinsic feedback is promoted through a larger HKA bandwidth in the gameplay. This adoption may look like the following: The screen or the skeleton is blackend, so that the user can not improve his performance visually anymore. After a defined time, the screen comes back as before and the game continues.

In this phase of no external feedback, the user must rely on his body and has to feel if the HKA and body position is right. This may help in the motor learning of the user. This thesis is again supported by presented evidence of differentiated learning. At the end of the game, again a detailed anaylsis would be prenseted to check the errors in the “black phase”.

Considering possible fields of application, sports clubs may be a good choice. As mentioned in the theoretical part of this work, a lot of money and time can be saved, when doing adequate prevention work with athletes. As this system is cost-effective and usable, it fulfils these needs.

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List of Figures

List of Tables

Appendix

A. Questionnaire in paper form

Willkommen!

Herzlichen Dank für deine Teilnahme an der Umfrage zum Thema Nutzbarkeit und Gebrauchstauglichkeit eines Kinect-basierten, prototypischen Programms zur spielerischen Prävention von Kniebeschwerden- und Verletzungen in Form eines Skirennens.

Auf den folgenden Seiten wirst du als BewegungsexpertIn über die Nutzbarkeit und Gebrauchstauglichkeit des von dir getesteten Systems befragt. Dieser Vorgang sollte nicht länger als **5 Minuten deiner Zeit** beanspruchen. Ich bitte dich darum, den Fragebogen unbedingt vollständig auszufüllen, da deine Daten ansonsten für meine Erhebung nicht berücksichtigt werden können.

Mit dem Starten der Umfrage stimmst du zu, dass deine Daten zum Zweck der wissenschaftichen Forschung, von mir anonymisiert und vertraulich, sowie unter Einhaltung des Datenschutzes verwendet werden dürfen.

Vielen lieben Dank!

Frage 1:
Geschlecht

- ○ weiblich
- ○ männlich

Frage 2:
Alter

- ○ 20-29
- ○ 30-39
- ○ 40-49
- ○ 50-59
- ○ 60-69

Aufbau des Fragebogens

Auf der nächten Seite werden 10 Aussagen über die Gebrauchstauglichkeit und 5 Aussagen zur Evaluation des getesteten Spiels dargestellt.
Bei der Bewertung der Aussagen ist wie folgt vorzugehen: Die jeweilige Aussage wird von 1-5 bewertet, wobei "1" eine Ablehnung der Aussage, "5" eine Zustimmung der Aussage bedeutet.
Dies ist unterhalb exemplarisch dargestellt.
Kann eine Aussage nicht eindeutig beantwortet werden, wird "3" ausgewählt.

Ich denke, dass ich das System gerne häufig benutzen würde.

	1	2	3	4	5	
Stimme überhaupt nicht zu	◉	○	○	○	○	Stimme voll zu

Frage 2:
Ich fand das System unnötig komplex.

	1	2	3	4	5	
Stimme überhaupt nicht zu	○	○	○	○	◉	Stimme voll zu

Gebrauchstauglichkeit - Usability

Frage 4:
Ich denke, dass ich das System gerne häufig benutzen würde.

	1	2	3	4	5	
Stimme überhaupt nicht zu	○	○	○	○	○	Stimme voll zu

Frage 5:
Ich fand das System unnötig komplex.

	1	2	3	4	5	
Stimme überhaupt nicht zu	○	○	○	○	○	Stimme voll zu

Frage 6:
Ich fand das System einfach zu benutzen.

	1	2	3	4	5	
Stimme überhaupt nicht zu	○	○	○	○	○	Stimme voll zu

Frage 7:
Ich glaube, ich würde die Hilfe einer technisch versierten Person benötigen, um das System benutzen zu können.

	1	2	3	4	5	
Stimme überhaupt nicht zu	○	○	○	○	○	Stimme voll zu

Frage 8:
Ich fand, die verschiedenen Funktionen in diesem System waren gut integriert.

	1	2	3	4	5	
Stimme überhaupt nicht zu	○	○	○	○	○	Stimme voll zu

Frage 9:
Ich denke, das System enthielt zu viele Inkonsistenzen.
Hinweis: "Inkonsistenz" kann auch als Widersprüchlichkeit oder Unstimmigkeit verstanden werden.

	1	2	3	4	5	
Stimme überhaupt nicht zu	○	○	○	○	○	Stimme voll zu

Frage 10:
Ich kann mir vorstellen, dass die meisten Menschen den Umgang mit diesem System sehr schnell lernen.

	1	2	3	4	5	
Stimme überhaupt nicht zu	○	○	○	○	○	Stimme voll zu

Frage 11:
Ich fand das System sehr umständlich zu nutzen.

	1	2	3	4	5	
Stimme überhaupt nicht zu	○	○	○	○	○	Stimme voll zu

Frage 12:
Ich fühlte mich bei der Benutzung des Systems sehr sicher.

	1	2	3	4	5	
Stimme überhaupt nicht zu	○	○	○	○	○	Stimme voll zu

Frage 13:
Ich musste eine Menge lernen, bevor ich anfangen konnte das System zu verwenden.

	1	2	3	4	5	
Stimme überhaupt nicht zu	○	○	○	○	○	Stimme voll zu

Evaluation: Prävention und Gesundheitsförderung

Frage 14:
Das System erfasst die Beinachse ausreichend genau für ein präventives Training.

	1	2	3	4	5	
Stimme überhaupt nicht zu	O	O	O	O	O	Stimme voll zu

Frage 15:
Ich kann das System für ein präventives Knie- und Beinachstentraining weiterempfehlen.

	1	2	3	4	5	
Stimme überhaupt nicht zu	O	O	O	O	O	Stimme voll zu

Frage 16:
Das System eignet sich zur allgemeinen Gesundheitsförderung.

	1	2	3	4	5	
Stimme überhaupt nicht zu	O	O	O	O	O	Stimme voll zu

Frage 17:
Das System zeigt eine adäquate Fehlermeldung bei zu großer Abweichung der Beinachse an.

	1	2	3	4	5	
Stimme überhaupt nicht zu	O	O	O	O	O	Stimme voll zu

Frage 18:
Ich würde das System im Rahmen der Gesundheitsförderung zum Einsatz bringen.

	1	2	3	4	5	
Stimme überhaupt nicht zu	O	O	O	O	O	Stimme voll zu

Frage 19:
Zum Schluss bitte ich dich, mir eine prägnante Kritik zu dem getesteten System zu geben.
Sowohl positives, als auch negatives Feedback erwünscht.

Dein Beitrag zu meiner Arbeit ist wertvoll und hilfreich. Dank deiner Angaben können wichtige Erkenntnisse zur Weiterentwicklung von digitalen Technologien im präventiven und gesundheitsförderlichen Einsatz gewonnen werden.

Falls du noch weitere Fragen zur Umfrage, dem getesteten System oder meiner Arbeit hast, kontaktiere mich gerne persönlich oder schreibe mir: dh151804@fhstp.ac.at.

Vielen Dank für deine Teilnahme!

Liebe Grüße
Dominic Ledinger

B. Survey data

lfd-nr	gender	age	EVA1	EVA2	EVA3	EVA4	EVA5
1	2	1	5	5	4	3	4
2	2	2	4	3	1	1	1
3	1	3	3	3	4	2	4
4	1	1	5	4	4	4	4
5	2	2	4	4	3	4	4
6	2	2	4	4	4	4	4
7	2	1	5	5	4	5	5
8	1	1	2	2	4	2	4
9	1	2	5	5	4	5	5
10	1	2	5	4	5	5	4

SUS1	SUS2	SUS3	SUS4	SUS5	SUS6	SUS7	SUS8	SUS9	SUS10
4	4	4	3	5	1	5	2	4	2
1	2	4	2	3	2	4	2	3	1
4	1	5	1	3	1	5	1	3	1
3	2	5	2	4	1	5	2	4	1
3	1	4	1	3	1	5	2	5	1
4	1	4	1	4	1	5	1	4	1
4	4	4	3	2	1	5	1	4	1
3	1	5	1	4	4	5	1	5	1
5	1	5	2	5	1	5	1	5	1
2	2	4	1	4	2	3	2	4	1

Total SUS Score	81,3
Std.Dev	9,8
95% Confidence Interval	6,078434
Upper CI Bound	84,3
Lower CI Bound	78,2

Das Spiel ist spaßig und motivierend; die Fehlermeldungen sind zwar gut, werden aber im Spielbetrieb kaum wahrgenommen, da zu unauffällig. Es sind allgemein sehr viele Elemente im Spiel, man weiß zu Beginn nicht, wohin man zuerst schauen soll. Das Spiel könnte ruhig noch länger dauern oder eine dynamische Bewegung einfordern.
Visuelle Fehlermeldung wäre besser als schriftliche Verbesserung. Video/ Schnitt war nicht adequat für das System. Beinachse wurde gut erfasst. Vielleicht kann sie auch dynamisch gemessen werden. Korrektur sollte anderst gestaltet werden. Wirkt eher ablenkend. Programm sollte mehr Anreiz beinhalten, ansonsten wird es fad. Evt. dynamischer gestalten. Sehr kurze Abfahrt. Programm sollte noch erweitert werden (Design, Struktur, Erklärung, Verschiedene Optionen zu Pistenabfahrten erc.) um in die Regelversorgung zu gelangen.

positiv: durch vorgegebene Parameter (Zeit, höhere Gewschwindigkeit durch tiefe Hocke) wird man ermutigt effektiver zu trainieren. leider: der nötige Blickkontakt/Fokus auf die Korrektur am Screen links oben veranlasst, dass man sich wenig auf die Skipiste konzentrieren kann (das wäre genau das Lustige)
Erkennung der Beinachsen hat schnell und gut funktioniert. Mehr Anreiz um sich auszubelasten würde ich positiv finden.
System +++ Fehlermeldung rechts oben am Bildschirm eher unpassend Vielleicht ist eine Optische Fehlermeldung (Knie rot markieren u. PFEIL innen u. außen) am betroffenen KNIE übersichtlicher
es sind zu viele Informationen am Bildschirm, welche man nicht alle gleichzeitig wahrnehmen kann -vor allem am Anfang. ev noch genauere Erklärung aller Funktionen? Wär gut wenn man auch die Schwünge des Skifahrers steuern könnte mit einer Hüftbewegung.
sehr lustig tw die Beinachse nicht exakt
Positiv fand ich, dass man mit dem System alleine trainieren kann.
Um es interessanter zu gestalten fehlt noch etwas abwechslung, ev. unterschiedliche Strecken, ev. "Ablenkungen" entlang der Strecke, Musik?...