UNIVERSITY OF TWENTE.

Faculty of Electrical Engineering, Mathematics & Computer Science

Using Depth Sensing and Augmented Reality to Improve Ski-learning.

Jop Paulissen
B.Sc Thesis
February 2018

Supervisors:

Dr. Job Zwiers

Robby van Delden

Telecommunication Engineering Group
Faculty of Electrical Engineering,
Mathematics and Computer Science
University of Twente
P.O. Box 217
7500 AE Enschede
The Netherlands

Abstract

This research focusses on the creation of an augmented reality ski-learning game stimulated by the introduction of new exciting hardware. This AR based hardware, like Microsoft's Hololens as well as Kinect, opens up new possibilities to make the game more enjoyable, more useful and can help leisure skiers by presenting them new types of feedback. This game uses depth sensing technology to present live feedback to the player and uses motion capture to construct a skiing trainer that can be mimicked by the user.

Acknowledgements

This project was not possible without the incredible support, feedback and helpful ideas from my supervisor dr. Job Zwiers from the University of Twente. His insights, knowledge and enthusiasm of the addressed subjects helped enormously during my graduation process. I would also want to thank my critical observer from the University of Twente Robby van Delden for great feedback and new insights. I would also like to thank the client of the project, Michiel Groot-Koerkamp, for providing me the opportunity to work on such an interesting and enjoyable project bachelor assignment. Also, my appreciation to all users willing to participate it the tests that I conducted. Lastly, I would like to thank my friends and family for their support and new insights during the project.

TABLE OF CONTENT

List of Figures

List of Abbreviations

Abbreviation	Description
AR	Augmented Reality
HMD	Head-Mounted Display
IM	Intrinsic Motivation
EM	Extrinsic Motivation
SMS	Sport Motivation Scale
BRSQ	Behavioural Regulation in Sport Questionnaire

1 INTRODUCTION

1.1 PROBLEM STATEMENT

When you want to go practice your skiing skills in the Netherlands, you'd have to visit one of the few artificial ski venues available. This could take valuable time and money, therefore many people wait till they have the opportunity to visit a real skiing slope in the mountains. This means that people don't practice as much as they possibly want to. The client, Michiel Groot-Koerkamp, specializes in portable revolving slopes where people can train their skiing abilities on. This however could become monotonous quite easily. To counter this, the idea arose to create an Augmented Reality application using a revolving ski slope. This application contains different types of hardware that adds elements, which can boost the impact of the skiing training. That is what is being researched in this report.

1.2 RESEARCH QUESTIONS

This thesis will discuss research where an AR game has been created for a portable ski slope by using different types of hardware. Therefore, the main research question is:

RQ: "How to create an augmented reality skiing application for on a portable slope where different types of hardware work together to support the ski-learning process ?"

To answer this question other sub research questions have to be answered. First, a literary research has been conducted to find out what types of hardware can contribute the best to the AR skiing game.
SQ1: "What type of hardware can be used best to add new elements to an AR skiing game?"

The setup of the game in combination with the portable ski slope should be examined. The type of hardware has been examined and elements have been considered that can be added to the AR skiing game. Therefore, the second sub question is:
SQ2: "What types of new elements can be implemented into the AR skiing game to support the ski-learning process?"

Lastly an evaluation has been conducted to find out the effects of the different types of elements put into the game. Therefore, the last sub research question is:

SQ3: "How do players of the game perceive the different types of elements in the game?"

1.3 OUTLINE OF THE DOCUMENT

Chapter 2 contains the State of the Art review on various important topics, such as Augmented Reality, Depth Sensors and AR Head devices. This chapter contains the answers to the first sub research question and a partial answer on the second sub research question. Chapter 3 discusses the methodology and techniques used in this research. Next, Chapter 4 contains the ideation phase of the project. Here, the hardware of choice is examined and different types of elements are discussed. Also, a product idea is concluded. Then in Chapter 5 a Lo-Fi prototype and a Hi-Fi prototype are created to define the product specification, which are discussed. Chapter 6 describes the process of the realization phase and concludes with a product prototype of the game. Chapter 7 describes the evaluation phase where user tests were conducted and reviewed. In Chapter 8 a conclusion is drawn and discussion is addressed. Chapter 9 recommend topics and ideas for future research.

2 STATE OF THE ART REVIEW

In this State of the Art review certain important topics will be discussed. In chapter 2.1 Augmented Reality and HMD's will be discussed and a comparison will be made to find out what the best HMD is for this project. In chapter 2.2, depth sensors will be discussed as it has been chosen as the hardware of choice. A second comparison will be made to figure out which depth sensor is best for this project. In chapter 2.3 motivation for participating is discussed. First the differences between types of motivation will be explained, after which several types of questionnaires will be thoroughly analysed to find out which one fits this context optimally.

2.1 AUGMENTED REALITY

Main Research Requirement Focus: *"How to create an* ***augmented reality*** *skiing application for a portable slope where different types of hardware work together to support the ski-learning process ?"*

This project is based upon Augmented Reality (AR) technology as its basis. As defined by Carmigniani et al., 2010, AR is *"a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it."* There are many different types of AR technology in existence. For example, one category are the recognition based AR technologies, which projects digital images on physical objects. Another is location based AR, which uses GPS location to perform images. A third example is the superimposition based AR, which provides an 'alternate' view of the object in concern, either by replacing the entire view with an augmented view of the object or by replacing a portion of the object view with an augmented view .Some types make use of other types of AR (i.e. superimposition uses recognition based AR), but defined by Azuma et al., 2001 all types of AR system share to following properties:

- Real- and virtual elements will be blended within a real environments;
- Real-time interactive elements;
- Accurate alignment of real and virtual objects in 3D, without accurate registration, the illusion that the virtual objects exist in the real environment is severely compromised.

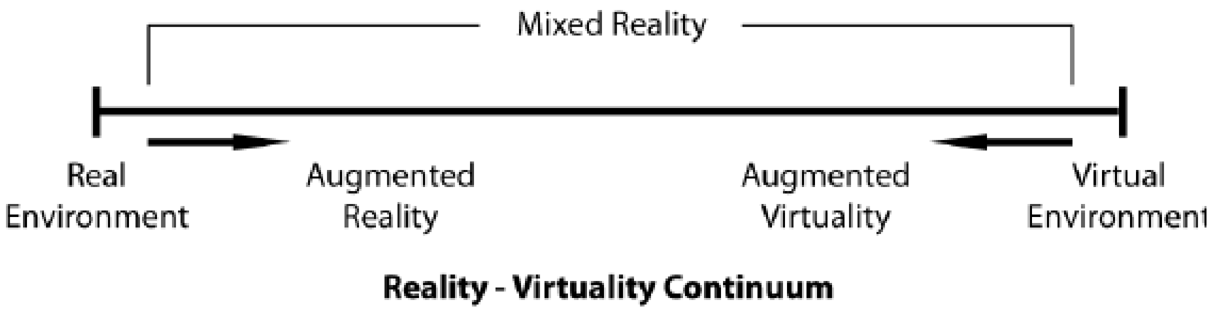


Figure 2.1. *Simplified representation of a Reality-virtuality Continuum by Milgram et al., 1994*

Milgram, Takemura, Utsumi, & Kishino, (1994) defined a continuum of real to virtual environments. In this continuum, which can be seen in **Figure 2.1**, AR is part of the 'Mixed Reality' area. Next to AR, the continuum distinguishes an environment with no virtually displayed objects and information, a completely virtual environment where there are no real objects and real environments are visible, but only the virtual objects and information (VR), and a virtual environment where both virtual objects and real-world objects are visible in the environment which is called Augmented Virtuality (AV). VR is used in different types of fields, such as military training, healthcare, construction and of course games. An example of the usability of AV is when an aircraft maintenance engineer uses a visualization of a real time model of an engine in flight. He can see the simulation of the real-time engine on a computer screen to search for errors or help the pilots who are thousands of kilometres away.

AR is not limited to a particular type of display nor is it limited to the sense of sight. It can apply augmented senses, smell, touch and hearing as well. This is what was used during the first iteration of the usage of 'Augmented Reality' which predated the digital era. In the 1962 Morton Heilig, a cinematographer, constructed the what he called 'The Cinema of the Future', named Sensorama. In this project he would draw the viewer into the onscreen activity by augmenting all the senses in an effective manner. In 1968 Ivan Sutherland was the first one to create an augmented reality system using an optical see-though head-mounted display (HMD), which can be seen in **Figure 2.2** (Sutherland & E., 1968). This was the first HMD created and the foundation for the HoloLens and other AR HMD's available at this moment. A HMD is an object that a person could put on his head which can construct AR, AV and AR environment with the use of screens on the inside of the structure. The first digital representation of AR technology was made by Myron Krueger. His "Videoplace" [1] was a room that allows users to interact with virtual objects. The first AR game, ARQuake, developed in 2005 by Bruce Thomas was demonstrated during the International Symposium on Wearable Computers in 2005 (Carmigniani et al., 2010).

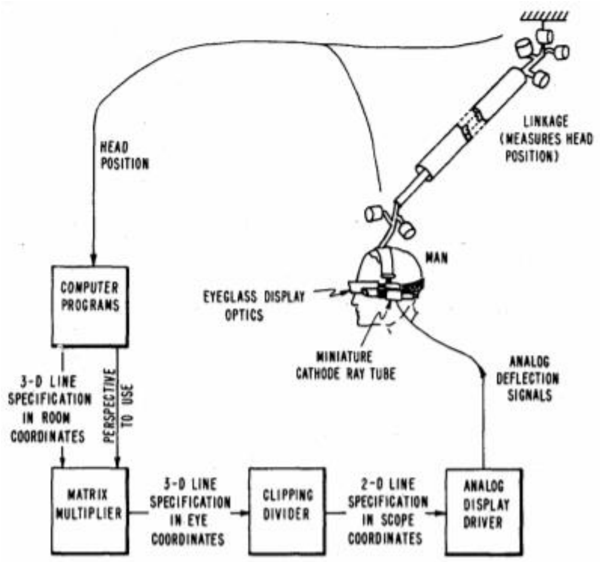


Figure 2.2. *The parts of the three-dimensional display system by Sutherland*

The Gartner Hype Cycle provides a graphic representation of the maturity and adoption of technologies and applications, and how they are potentially relevant to solving real business problems and exploiting

[1] Link to his work: https://www.youtube.com/watch?v=dmmxVA5xhuo

new opportunities. On the Gartner Hype Cycle for Emerging Technologies AR has seen a rise on this cycle. Companies use the Hype Cycles to educate themselves about promises of an emerging technology within the context of their industry and individual appetite for risk. There are five key phases within the Hype Cycles (Linden & Fenn, 2003):

- *Innovation Trigger:* The kick off of a potential technology breakthrough. Normally no products exist yet but the concept stories trigger publicity;
- *Peak of Inflated Expectations:* Success stories are produced. Companies will go on with their products or will stop development;
- *Trough of Disillusionment:* Interest in the technology fades away as products fail. Companies stop developing or continue improving to continue investments;
- *Slope of Enlightment:* Product becomes more understood. More enterprises fund the pilots.
- *Plateau of Productivity:* Mainstream adoption starts to take off. The technology's broad market applicability and relevance are clearly paying off.

In 2011 AR technology was put in the ‘Peak of Inflated Expectations’ area with an expected lifespan of 5 to 10 years. Some companies developing AR stop producing (Google Glass), but some continue development (Microsoft HoloLens, Meta). Now in 2017 it is put in the ‘Through of Disillusionment’ with also an expected lifespan of 5 to 10 years. Surviving providers satisfy the early adopters, but products still fail and stop developing which keeps the mainstream public cautious.

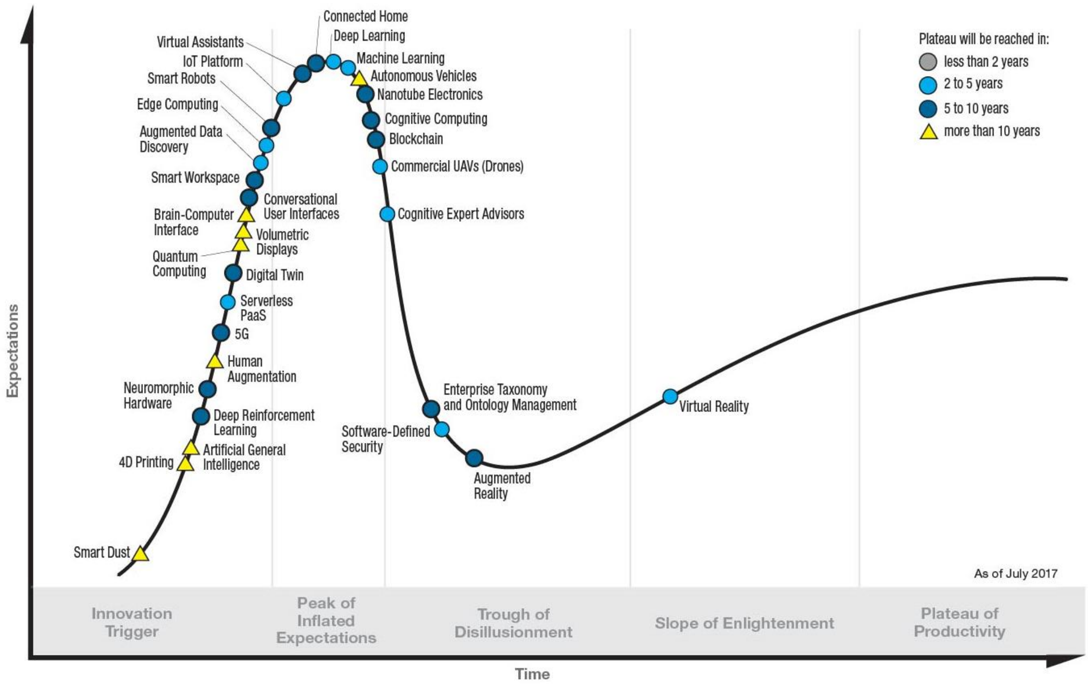


Figure 2.3. *Gartner Hype Cycle for Emerging Technologies, 2017*

2.1.1 Head-mounted Displays (HMD)

Nowadays AR technology is used in different ways. The most used ones are HMD's like the Microsoft HoloLens and the Meta 2 AR, and AR technology on tablets/phones. An example of the latter is the immensely popular game Pokémon GO. Since Sutherland made the evolution of HMD AR possible the development of these machines has not stood still. According to calculations made by Digi-Capital the prediction is that the value of the AR technology market will grow from 3.9 billion US dollars in 2016 to 82 billion US dollars in 2021. In this part the HMD's will be discussed.

Google Glass

Google was one of the first to start the idealisation of the modern augmented reality HMD. Their product, called Google Glass, was being constructed for developers who could create their own applications for the hardware. They were also the first company to start a market for consumers. The product is no longer in production, since the company got too much negative attention and could not fulfill the demands.

Microsoft Hololens

In March 2016 Microsoft released its developer edition of the HoloLens, a HMD that was one of the first computers running the Windows Mixed Reality platform under Windows 10 operating system. The 'wearable computer' has four cameras that track movement and will place virtual objects realistically in the wearers view.

Metavision Meta 2 AR

In 2013 Meta launches a crowdfunded Kickstarted campaign which resulted in $194.444. A year later the Meta 1 Development Kit was released. AR enthusiast and Fortune 500 companies including Boeing, Toyota and Caterpillar were now customers of the company. On March 2016 Meta starts accepting pre-orders for the Meta 2 Development Kit. This product offers an industry leading Field of View, 2.5K resolution and direct hand interactions.

2.1.2 Conclusion

The Metavision Meta 2 AR was chosen for its leading field of view (i.e. 90 degrees) and high resolution. However, after ordering the device the company did not deliver it on time. Therefor another AR HMD had to be picked. The decision fell on the HoloLens, because it was best accessible during the project. Thus, the project uses the HoloLens as it's HMD.

2.2 DEPTH SENSORS

Main Research Requirement Focus: "How to create an augmented reality skiing application for on a portable slope where ***different types of hardware*** *work together to support the ski-learning process ?"*

Depth sensors are used for tracking the player's location and used for Motion capturing certain movements of a person, which will be integrated into a game style. There are many different types of depth sensors, which all can be optimally used for a specific situation. Because of its possibilities and its broad usability the choice fell on using a depth sensor for this project.

2.2.1 Depth Sensor Requirements and Comparison

There are sensors that work best for medium-range indoor applications, like the Intel SR300[2], sensors that are used for tracking hand gestures for small-range indoor applications, like the Leap Motion[3], and sensors that work best for large-range outdoor applications, like the Stereolabs ZED Stereo Camera[4]. Stimulant[5], a company that uses emerging technologies to transform static physical spaces into dynamic interactive environments, compared 11 different types of depth sensors to find out which application is best use in which environment. In ***Appendix A, specification comparison Depth Sensors*** the documented comparison is displayed.

The depth sensor that is necessary for this project should meet some function requirements. It should work steadily on a medium-range distance. The price should be relatively cheap. Skeleton tracking is not necessarily a requirement, but will make the process of creating and usability more accessible. When looking for perfect matches it is found that the following depth sensors fit the requirements:

- Microsoft Kinect v1;
- Microsoft Kinect v2;
- RealSense R200;

To find out which one is optimal for the environment of the project a comparison will be made of these three with new requirements: the possibility to full body tracking and the availability of the product. The results can be seen in **Figure 2.4**.

---

[2] https://software.intel.com/en-us/realsense-sdk-windows-eol
[3] https://www.leapmotion.com/product/vr#113
[4] https://www.stereolabs.com/zed/specs/
[5] https://stimulant.com/depth-sensor-shootout-2/

	Full Body Tracking (All Joints)	Availability
Microsoft Kinect v1	2 bodies trackable	Discontinued, can be bought elsewhere
Microsoft Kinect v2	6 bodies trackable	€99,99
RealSense R200	Only waist and up	€99,95

Figure 2.4. *Comparison of three depth sensors based on ability of skeleton tracking and availability*

The RealSense R200 is not suitable for this project, because of its lack in Full Body Tracking. The Microsoft Kinect v1 is not for sale anymore but can be bought through other means. A comparison of these two depth sensors will now be made.

Kinect v1 and Kinect v2 comparison

Although the first Kinect is discontinued, it is still possible to buy it via other ways. In an article of Wasenmüller and Stricker (2017) a thorough comparison between the two Kinect's is conducted. They state that the Kinect v1 uses the Pattern Projection principle, known infrared patterns are projected into the scene and out of its distortion the depth is computed. to measure depth, whereas the Kinect v2 contains a Time-of-Flight (ToF) camera and determines the depth by measuring the time emitted light takes from the object and back. When increasing the distance the accuracy will exponentially decrease when using the Microsoft Kinect v1, while the Kinect v2 has a constant accuracy in form of an offset of -18mm. In addition, Kinect v1 incorporates the pattern in the depth images, which is difficult to compensate. For Kinect v2 all central pixels show a similar accuracy; only the image corners deviate. On the other hand, the precision of the depth images is higher for Kinect v1. This holds for flat surfaces, but especially for depth discontinuities, where flying pixels occur for Kinect v2. Flying pixels are erroneous depth estimations, which occur close to depth discontinuities . These flying pixels occur with every device that uses ToF. Furthermore, the depth estimation of Kinect v2 is influenced by the scene colour, whereas Kinect v1 is unaffected by colour. In contrast to Kinect v1, Kinect v2 depth images are influenced by the multipath interference effect, meaning that concave geometry is captured with bulges (Wasenmüller & Stricker, 2017).

2.2.2 Conclusion

After a comparison of 11 different depth sensors[6] a conclusion has been made on which depth sensor is most usable in the project environment. Three key requirements where constructed and used to deduct the best sensor. At the end the best depth sensor seems to be the Microsoft Kinect v2. It is one of the cheaper depth sensors ($99,99), it has the perfect medium range (0.5m – 4.5m) and includes the

[6] Source: https://stimulant.com/depth-sensor-shootout-2/

possibility to track six skeletons at the same time. Beside being the best depth sensor for this project, it was also one that was available during the duration of the project.

2.3 LEARNING STYLES IN SPORTS

When looking for ways to effectively instruct people it is important to find the optimal way to do this. There are different learning styles that people prefer in certain environments. First, the different types of learning styles will be discussed and will then be placed into a exercise environment to find the optimal way to instruct people.

2.3.1 Differences in Learning Styles

According to the Experiential Learning Cycle (Kolb, 1984), learning involves four phases: concrete experience (feeling), reflective observation (reflection), abstract conceptualization (thinking), and active experimentation (doing).

- **Concrete Experience (CE) -** A new experience of situation is encountered, or a reinterpretation of existing experience.
- **Reflective Observation (RO)** of the new experience. Of particular importance are any inconsistencies between experience and understanding.
- **Abstract Conceptualization (AC) -** Reflection gives rise to a new idea, or a modification of an existing abstract concept.
- **Active Experimentation (AE) -** The learner applies them to the world around them to see what results.

Effective learning is seen when a person progresses though this cycles of four stages. This cycle can be rewritten to the following cycle: Experience → Reflection → Conceptualise → Test → […] (McLeod, 2013). Kolb explains that different people prefer a different learning style, which are caused by different influences in a person's life. The preferred learning style is a product of two pairs of variables/choices that people make. There is the processing continuum and the perception continuum. The perception continuum describes our preferred means of acquiring new information (from CE to AC) and the processing continuum refers to how we make sense of things (from AE to RO). Kolb believes that both variables can't be performed at once (e.g. think and feel) and that a learning style is a combination of these two choice decisions. Lowy & Hood (2004) put this construction in a two-by-two matrix, which can be seen in **Figure 2.5**.

	Doing (AE)	**Watching (RO)**
Feeling (CE)	Accommodating (CE/AE)	Diverging (CE/RO)
Thinking (AC)	Converging (AC/AE)	Assimilating (AC/RO)

Figure 2.5. *Two-by-two matrix of the different learning styles*

The four quadrants (e.g. accommodating, diverging, converging and assimilating) have different ways of learning, because of the different combinations of preferred learning styles.

- **Accommodating learn style**: using other people's analysis and information to take a practical and experiential approach.
- **Diverging learn style**: these people prefer to watch rather than do and view concrete situations at several different viewpoints to obtain information.
- **Converging learn style**: solving problems and using their learning to find solutions to practical issues. Preferring technical tasks and are less concerned with people and interpersonal aspects.
- **Assimilating learn style**: ideas and concepts are more important than people. They require good clear explanation rather than practical opportunity. They excel at understanding wide-ranging information and organizing it in a clear logical format.

2.3.2 Learning Styles in an Exercise Environment

Different learning styles can be effective in different environments, but since different people prefer different learning styles it is important to figure out what type of learning people in the exercise environment prefer. In an experiment conducted by González-Haro, Calleja-González, and Escanero (2010) a total of 71 athletes took part into the study. The athletes played different sports or practised recreational and partook on different levels in the sport. The experiment found out what percentage of the athletes preferred a certain learning style. The percentages can be seen in **Figure 2.6a** (different sports/recreational) and **Figure 2.6b** (level of performance).

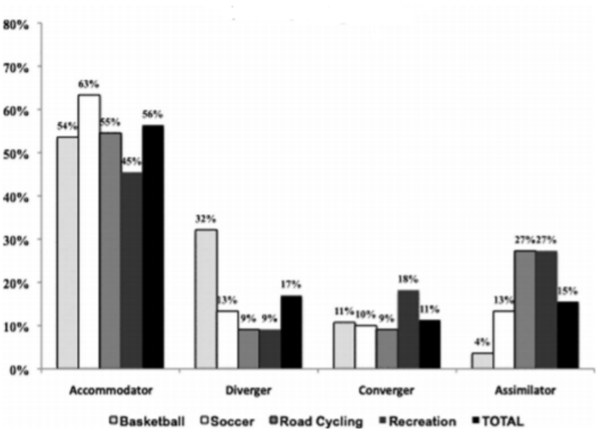


Figure 2.6a. Learning styles expressed as a percentage based on type of sport/recreation

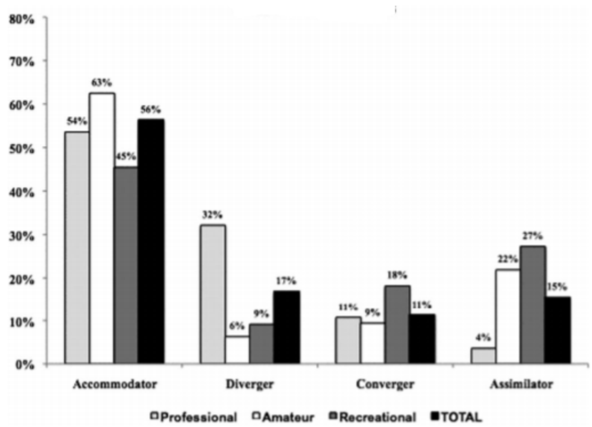


Figure 2.6b. Learning styles expressed as a percentage based on level of performance

2.3.3 Conclusion

When focussing on recreational exercise it is visible that 55% of the recreational athletes prefer the accommodation learning style approach. When looking at the other sports, including level of performance, it's clear that this approach is the most preferred by the athletes.

2.4 MOTIVATION

To test the impact and effectiveness of the application a questionnaire will be used that can indicate the amount of impact the application has. First intrinsic and extrinsic motivation are discussed, then several types of questionnaires are compared to find out which one is most suitable for this project.

2.4.1 Intrinsic and Extrinsic Motivation

The Self-Determination Theory (SDT; E. Deci & Ryan, 1985), distinguishes between different types of motivations based on the different reasons or goals that give rise to an action. These are based on the identified needs that, if satisfied, allow optimal function and growth. These three innate needs are:

- **Competence**, wanting to experience mastery and being able to control the outcome of the situation;
- **Relatedness**, wanting to interact with, be connected to, and care for other people;
- **Autonomy**, wanting to be in control of one's own life; however, according to (Deci & Vansteenkiste, 2004) this doesn't mean that someone want to be completely independent of other people.

There are three basic types of motivation: amotivation (AM), intrinsic motivation (IM) and extrinsic motivation (EM). People are often motivated by factors such as grades, money and fame to name a few. This, being driven by external rewards, is what defines EM. IM on the other hand is defined as the doing of an activity for its inherent satisfactions, rather than for some separable consequence. When intrinsically motivated a person is moved to act for the fun or challenge entailed, rather than of external prods, pressures, or rewards (Ryan & Deci, 2000). Within the SDT there are several subtheories. The first subtheory is Cognitive Evaluation Theory (CET) which specifies the factors on social contexts that produce variability in IM (Deci & Ryan, 1985). *"CET argues that interpersonal events and structures (e.g., rewards, communications, feedback) that conduce toward feelings of competence during action can enhance intrinsic motivation for that action because they allow satisfaction of the basic psychological need for competence."* (Ryan & Deci, 2000). Feelings of competence, however, must be accompanied by a sense of autonomy to enhance IM, which mean that people must feel that their actions are self-determined. The last need, the need of relatedness, will flourish the IM when present. For example, Grolnick & Ryan (1989) found that when a child finds his teacher non-caring, thus not fulfilling the relatedness needs, that the IM for the course diminishes.

A taxonomy of IM hypothesized by Vallerand and Bissonnette (1992) divided the global IM construct into three types: IM to know, IM to accomplish things and IM to experience stimulation. IM to know relates to performing an activity for the pleasure and satisfaction someone experiences whilst learning and understanding new things. IM to accomplish things relates to feeling competent and the pleasure and satisfaction someone experiences when accomplishing something. Lastly, IM to experience stimulation relates to experiencing stimulating passion, like sensory pleasure or aesthetic experiences, whilst performing in an activity.

A second subtheory within the SDT is the Organismic Integration Theory (OIT). The OIT distinguishes different types of EM with its contextual factors. **Figure 2.7** illustrates the taxonomy of motivational types according to the OIT. The far left illustrates AM, which arises when someone is not valuing the activity, not feeling competent to do it, or does not believe it will result in the desired outcome (Ryan & Deci, 2000).

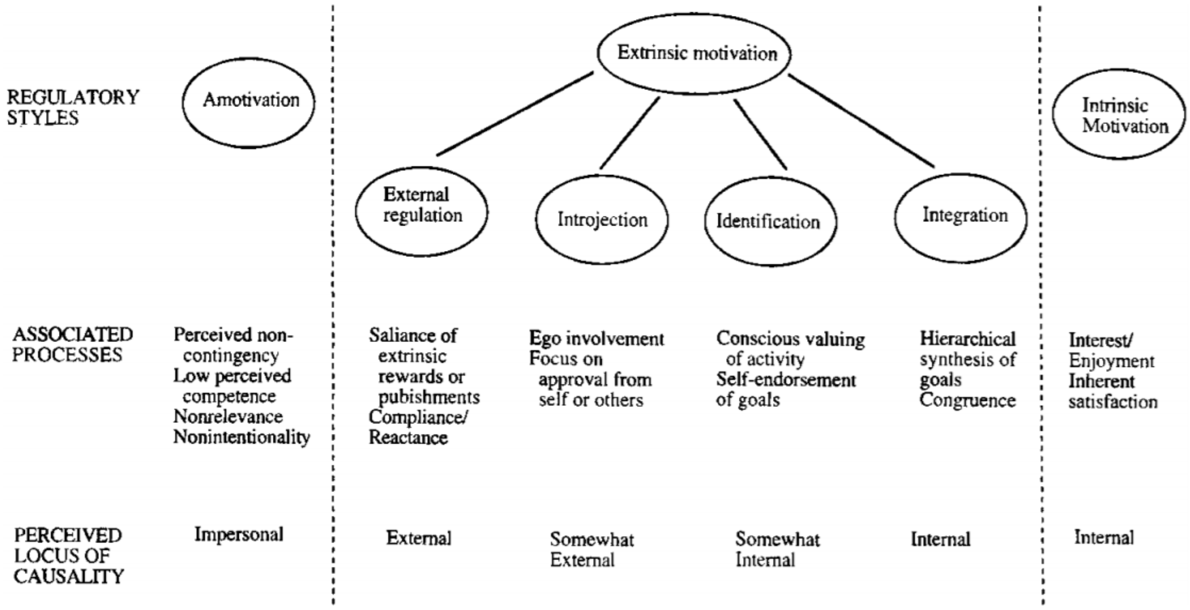


Figure 2.7 *Taxonomy of human motivation* (Ryan & Deci, 2000; Ryan, P. Connell, & Grolnick, 1992)

Originally people thought that EM was only obtainable by external contingencies like giving out rewards. R. Ryan, P. Connell, & Grolnick (1992), however, proposed that there were different types of EM. As can be seen in **Figure 2.7**, from lower to higher levels of self-determination you have:

- **External regulation,** behaviour controlled by external rewards. An athlete who engages into a sport to obtain praise or feel pressure from their peers.
- **Introjection,** behaviour controlled by internal pressure (e.g. guilt, anxiety). An athlete that trains to stay in shape for aesthetic reasons.
- **Identification,** behaviour controlled by judging it as important and, therefore, performing it out of choice. The activity is done to, for example, achieve personal goals, but is internally regulated and self-determined.
- **Integration,** *"occurs when identified regulations have been fully assimilated to the self. This occurs through self-examination and bringing new regulations into congruence with one's other values and needs. "* (Ryan & Deci, 2000)

Examples of the different motivational styles: a student can be unmotivated because he/she feels that the assignment is not worth the time and not valuable to this person (AM), the student can be motivated to study hard for a test out of curiosity and interest of the topic (IM) or the student is motivated because he/she wants to obtain a high grade to get approval from their superiors and wants to brag about it in class (EM). Looking at the project we want to obtain both intrinsic motivation and extrinsic motivation.

2.4.2 Measuring Motivation in Sports

There are several questionnaires available to measure the IM, EM and AM of playing a sport. In this chapter a summary of different questionnaires will be given and the best suitable questionnaire will be discussed.

SMS-28

Brière, Vallerand, Blais, & Pelletier, (1995) constructed the Échelle de Motivation dans les Sports (EMS), a scale for measuring motivation in sport. The scale, written in French, consists of seven subscales that measure different forms of motivation. Namely, the three IM styles by Vallerand and Bissonnette (1992; IM to know, IM to accomplish and IM to experience stimulation), three EM styles by R. Ryan, P. Connell, & Grolnick (1992; EM identified, EM introjected and EM external regulation, excluding integrated regulation) and amotivation. Pelletier et al. (1995) translated the French model to the English language calling it the Sport Motivation Scale (SMS), or the SMS-28.

SMS-6

Mallett, Kawabata, Newcombe, Otero-Forero, & Jackson (2007), however, revised the SMS-28 into SMS-6, because the old version does not contain the most autonomous form of EM, integrated regulation. They also state that the three IM factors are *"not empirically distinguishable"* and there are items cross-loading or not loading well onto hypothesized factors (Martens & Webber, 2002). Their version consist out of a general IM subscale, the EM types of SMS-28, but with integrated regulation included and amotivation.

BRSQ-8 and BRSQ-6

Lonsdale, Hodge, & Rose (2008) proposed another questionnaire: the Behavioural Regulation in Sport Questionnaire (BRSQ). Of this model two variants exist: BRSQ-6 with a single IM Subscale and the BRSQ-8 with the three IM Subscales proposed by Vallerand and Bissonnette (1992). Lonsdale et al., state that the BRSQ scores demonstrated equal or superior reliability and factorial validity in comparison to the SMS-28 and the SMS-6. Important to note: this scale was designed to use with competitive sport participants.

SMS-II

Pelletier, Rocchi, Vallerand, Deci, & Ryan, (2013) constructed a new SMS, calling it the SMS-II, which contains six subscales. They claim that the SMS-II addresses the limitations of the first SMS better than the SMS-6 or the BRSQ by Lonsdale, Hodge, & Rose (2008). However, Lonsdale, Hodge, Hargreaves, & Ng (2014) state in a paper that there is insufficient information to support the claim that the SMS-II is superior over BRSQ.

A critical review by Clancy, Herring, & Campbell (2017) evaluates the six most highly cited motivation questionnaires in the sport sector: Task and Ego Orientation in Sport Questionnaire (TEOSQ; Duda, 1989), Perceptions of Success Questionnaire (POSQ; Roberts, Treasure, & Balague, 1998), SMS-28 (Pelletier et al., 1995), BRSQ-6 (Lonsdale et al., 2008), Intrinsic Motivation Inventory (IMI; McAuley, Duncan, & Tammen, 1989) and the Situational Motivation Scale (SIMS; Guay, Vallerand, & Blanchard, 2000). A quick overview of the measures can be found in **Table 2.1**. Clancy et al., summarizes that the SMS is a well-supported, multidimensional questionnaire with a limitation that integrated regulation is

Construct	Measure	Items[7]	Subscales	Responses/item	Citations*
Motivation	SMS-28	28	7	1-7	2037 [8]
	SMS-6	24	6	1-7	154
	SMS-II	18	6	1-7	167
	IMI	16	4	1-7	1641
	SIMS	16	4	1-7	974
	BRSQ	24	6	1-7	267
Goal orientation	TEOSQ	12	2	1-5	850
	POSQ	13	2	1-5	553

Table 2.1. *Overview of the six most highly in the sport sector* ** citations based on Google Scholar results*

not assessed. However, this can be overcome by using SMS-II. The IMI is a flexible measure, but there are no subscales for EM of AM, thus focussing on, what the name implies, predominantly IM. The SIMS is a brief, non-sport-specific measure that uses a general IM and only uses two EM types. The POSQ is not usable for measuring motivation, but for measuring achievement goals in sport. Same goes for the TEOSQ which has measures of task and ego goal orientation in sport, and not measuring motivation. Lastly, the BRSQ is designed for use among competitive athletes, which makes it unsuitable for exercise or physical activity environments.

See ***Appendix C: SMS-II Questionnaire***.

[7] When there are multiple versions of the measure, the most commonly used version will be used
[8] Addition of the English and French articles

2.4.3 Motivation in Games

2.4.3.1 Intrinsic Motivation in games

Malone (1981) proposed a framework where the primary factors for making activities intrinsically motivated are challenge, curiosity and fantasy. He also specifically applied this to the design of computer games. According to Csikszentmihalyi (1979) intrinsically motivating activities can be described as: 1. The level of challenges must be able to be changed to match his skill with the requirements for action; 2. Isolation of the activity from external and internal stimuli that might interfere; 3. Criteria for performance must be set up so that someone can, at every given point, see how he is doing; 4. Feedback that shows the player how close he is to the criteria of performance must be in place; 5. Broad range of challenges, and different ranges of challenges to show the player what he can do.

All points, with number two as exception, make the activity challenging and are thus part of Malone's framework. Richard E. Mayer (2014) adds: *"Concerning challenge, the game should require performance at a level that is slightly higher than the player's current level of competence, which can be achieved by building progressively more difficult levels into a game"*, thus agreeing with the statements of Csikszentmihalyi. Mayer then states that the player has to be allowed to experience an enticing environment that goes beyond the player's normal experience in relation to fantasy. Lastly, by revealing holes in the player's knowledge curiosity can be maintained. Malone (1982) proposed heuristics for designing enjoyable User Interfaces (UI) and uses the three primary factors. It can be seen as a checklist for creating the UI.

See **Appendix D: Heuristics for Designing Enjoyable User Interfaces** for the framework.

In short, activities can be made intrinsically motivating by using the primary factors challenge, fantasy and curiosity. This, together with the UI heuristics, can be used to make the game more intrinsically motivating.

2.4.3.2 Extrinsic Motivation in Games

As discussed in Chapter 2.4.1, EM has four different subscales. In this part we want to find out what types of game elements to use in the project to create environments for the types of motivations.

Singleplayer games can be fun, but will most likely get boring quicker than multiplayer. Multiplayer gives the constant excitement of challenging other people and wanting to get better in the game just to beat them (Göbel, Hardy, Wendel, Mehm, & Steinmetz, 2010). Games against people will always play out differently, thus enhancing replayability and motivation. Multiplayer could be both intrinsically motivating and extrinsically motivating (introjection or external regulation).

Reeves & Read (2009) identified ten game mechanics that could positively increase the services of non-game applications: self-representation with avatars, navigating through a three-dimensional environments, narrative context, feedback and behaviour reinforcement, reputations (ranks and levels), marketplace and economies, competition within rules, teams, parallel communication systems, and time pressure. Although these are for non-game applications, some mechanics overlap with other sets of game elements found by researchers. For example, two studies suggest other sets of game elements. Ten elements, also called affordances, were set up by Hamari, Koivisto, & Sarsa (2014) and are in line with the mechanics Kumar (2013) identified. These ten are: *points, leaderboards, achievements/ badges, levels, story/theme, clear goals, feedback, rewards, progress and challenge.* Kumar, Hamari et al., and Reeves and Read found that points, leaderboards and levels are commonly used as important game elements for boosting extrinsic motivation. This is also the case in the research done by Franscisco-Aparicio, Gutiérrez-Vela, Isla-Montes, & Sanchez (2013) where they found that these three game mechanics: "could enhance feelings of competence", and therefore boost extrinsic motivation and performance (Przybylski, Rigby, & Ryan, 2010). So, filtering the identified game elements on the basis of: usage in games and effectiveness based on possible boost for motivation gives us three important game elements to investigate, which are: points, leaderboards, levels.

In an empirical evaluation, Mekler, Brühlmann, Tuch, & Opwis (2017) conducted a 4 x 2 between-subject online experiment (n=273). The independent variables were three of the most common game elements: points vs. leaderboard vs. levels vs. plain condition without any game elements. Mekler et al., (2017) attempted to empirically evaluate the impact of gamification elements on user performance, intrinsic motivation and satisfaction of autonomy and competence needs. This research was done by executing four different tests. One without game elements and three tests with each a different element.

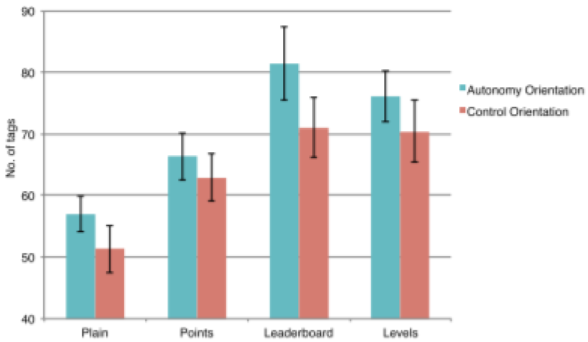


Figure 2.8a. *Average number of user-generated tags per condition. Error bars indicate standard error of the mean.*

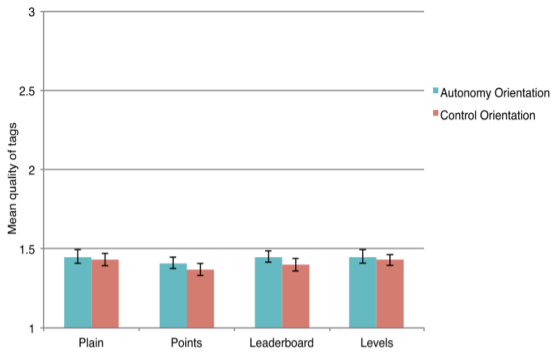


Figure 2.8b. *Average quality of user-generated tags per condition. Error bars indicate standard error of the mean.*

This evaluation showed that points, levels and leaderboards increased tag quantity compared to the plain condition tests (**Figure 2.8a**). It also showed that it has no influence on the quality of the tags (**Figure 2.8b)**. To test the intrinsic motivation aspect of the test, Mekler et al., made use of the Intrinsic Motivation Inventory (IMI). The results of the IMI showed that neither a significant main effect or a significant game element effected the intrinsic motivation. Because of the lack of effects on intrinsic motivation and tag quality it is suggested that points, levels and leaderboards function as an extrinsic motivation factor. So, users do it for the rewards rather than doing it for their own sake, which was expected.

2.4.4 Conclusion

In this section, motivation was explored and several conclusion can be drawn. First of all several types of IM and EM where found and explained. These types should be measured to find out what drives a player to practice his sport, because if that is clear a special game mode can make the player more motivated to use the installation. Several types of questionnaires were discussed and compared and a conclusion was drawn that the IMI was the best option to use. Although the SMS-II was also qualified to be used during the project, the choice was made to pick a more general motivation scale, because the experiment is not always in a sport environment. Then a research was conducted to find out what types of elements can motivate intrinsically and extrinsically. It was found that activities can be made intrinsically motivating by using the primary factors challenge, fantasy and curiosity. This, together with the UI heuristics, can be used to make the game more intrinsically motivating. It was also found that activities can be made extrinsically motivating when using points, levels and leaderboard. Multiplayer is also an important game element that boosts motivation and replayability.

2.5 Conclusion

Several conclusions can be drawn from the review. The first sub research question was:

“What type of hardware can be used best to add new elements to an AR skiing game?”

By deciding on using an AR HMD in combination with an depth sensor an comparison between different types was made. First, the AR HMD of choice was the Metavision Meta 2 AR, because of its leading field of view and high resolution. The device was not send in time to be used unfortunately, therefore the Microsoft HoloLens was used instead. Second, the choice of depth sensor was made based on an big comparison of 11 different sensors. It was concluded that the Microsoft Kinect v2 will be used for the project, because of it’s ability to track the users skeleton. This will open up many types of new elements to the AR skiing game.

The third research question was:

“How do players of the game perceive the different types of elements in the game?”

For this several questionnaires were reviewed. First it was found that people who want to practice on exercising prefer an accommodating approach, which means using other people’s analysis and information to take a practical and experiential approach. Therefore it is practical that the users can train skiing by actually doing it. It is concluded that the best questionnaire to test the application is the IMI. Using several components of this questionnaire and adjusting existing statements will make the questionnaire complete.

3 METHODS AND TECHNIQUES

To be able to answer the research questions of this project, it is necessary to design different gamified environments where each environment has a different kind of game element implemented. With this application an experiment can be conducted through user testing in the evaluation phase, which leads to a conclusion and a discussion about future work. Two processes are described in the next chapters that will secure quality of the application to fulfil the needs of the user. These processes consist of several methods which are also described.

3.1 DESIGN PROCESS FOR CREATIVE TECHNOLOGY

Creative Technology students often use The 'Design Process for Creative Technology' within their graduation projects (Mader & Eggink, 2014). This process consists of four phases that will guide students through the design process of the product/application and make clear and well-supported design choices. These four phases are: the ideation phase, specification phase, realisation phase and the evaluation phase. When following this process a clear product/application will be the result.

The Ideation Phase is the first step in the design process. As described in the document this phase focusses on evaluating early ideas with clients or users and using other user centred design techniques (the use of mock-ups, sketches, user scenarios and story boards) (Mader & Eggink, 2014). A better view and elaborated project idea and acquired problem requirements are the results of the Ideation Phase, which can be acquired through interviews with clients, users or user experts who characterize the needs, describe the problem setting and provide requirements. Also, a stakeholder identification is performed to understand how the users of the application work. These result in Personal, Activities, Context and Technologies (PACT, Benyon & Macaulay (2002)) user scenarios that describes the current way of working. Other results of the Ideation Phase are new ideas on: *"experience, interaction, as well as a service and business mode."*

When the Ideation Phase is completed and has delivered a clear product idea the Specification Phase will start elaborating the idea to a concept that is concrete, clear and feasible. Multiple ideas of prototypes will be created and explored, and a short evaluation and feedback loop will be applied. Discussions and evaluations on specification aspects of the prototype idea with the user-experts and end-users will lead to the rejection and alteration of prototype ideas and a PACT scenarios will be created that describes the usage of the application in a gamified environment during data cleansing activities. At the end of this phase functional and non-functional requirements are set up with the end-users and expert-users and will be prioritized using the MoSCoW method (van Vliet, 2008). The results of the Specification Phase are specifications on: experience, interaction, product, service and business.

In the Realisation Phase the prototype ideas and its fulfilled requirements will lead to the creation of a prototype. Because of the use of the MoSCoW method the order of implantation of functionalities is clear which will lead to a better prototype.

After the prototype has been constructed the Evaluation Phase commences. In this phase two different types of evaluation will be concerned: functional evaluation and user evaluation. A conclusion will be drawn from the outcomes of these evaluations and future work will be addressed.

The design process of Creative Technology that is suggested can be seen in ***Appendix B: Creative Technology Design Process***.

3.2 METHODS

During the description of the Design Process for Creative Technology a few methods were mentioned. Listed below are these methods including a explanation of what each method contains. The methods are: Stakeholder Identification & Analysis, User & Expert Interviews, PACT scenarios, Product Requirements & MoSCoW and Evaluation methods.

3.2.1 Stakeholder Identification & Analysis

To understand how users work and react in certain environments, especially the specific gamified environment in this experiment, a stakeholder identification and analysis is conducted. There are different variants on the definition for a stakeholder, but the definition of Dix, Finlay, Abowd, & Beale (2004) concerning stakeholder identification is chosen. This is because of its frequent use within software engineering projects. Dix et al., identifies stakeholders as: *"anyone whose jobs will be altered, who supplies or gains information from it, or whose power or influence within the organization will increase or decrease."* The goal of setting up a stakeholder identification and analysis is to gather information on the users who are affected by the application. Another goal is to identify the possible end-users of the product.

Sharp, Finkelstein, & Galal (1999) identified several types of stakeholders in their stakeholder identification methodology. The starting point is a set of stakeholder, called 'baseline' stakeholders, who provide information or supporting tasks to the baseline of the project. Another recognised group of stakeholders are the 'supplier' stakeholders, who processes or inspect tasks to the baseline. Lastly, Sharp et al., identified a stakeholder group as 'satellite's' interact with the baseline in a variety of ways. Because the 'baseline' stakeholders have the biggest influence on the project, this group can be identified as the most important group. Within this group Sharp et al., identified four different sub groups: users, who according to Eason (1988) can be identified into primary, secondary and tertiary users, developers, who create the product, legislators, who could apply regulations on the product and decision-makers, who have the most influence on the project, because of their controlling role.

3.2.2 PACT Scenarios

During the Ideation Phase and the Specification Phase, PACT scenarios will be constructed and used. PACT stands for people, activities, context and technology and are key points to think about during the construction of a scenario.. According to Benyon & Macaulay (2002), scenarios are useful methods to discuss a product, because it represents a concrete situation of the product. These so called PACT scenarios will be based upon the user and expert interviews and the stakeholder identification and analysis. Creating and using a user story, experiences of people in what they do and what they want, can help making the product clear to different parties. These user stories will be created by creating a conclusion based on the conducted PACT scenarios.

3.2.3 Product Requirements and MoSCoW

Product requirements are formulated to concretize and clear up the idea of the application which were formulated in the PSCT scenarios. These requirements are written down with its corresponding functionality. These corresponding functionalities are divided into two parts: functional and non-functional requirements. The main focus will be on the functional product requirements, because the effectivity of the product is being measured. Because of time restraints it won't be possible to address all functionalities of the product requirements, therefore the MoSCoW method is used to prioritize these requirements. This method contains out of four groups: 'Must haves', 'Should haves', 'Could haves' and 'Won't haves' (Clegg & Barker, 1994).

3.2.4 Evaluations

For evaluating the final product two types of evaluations were used. First, a modified version of the IMI-scale (modified version can be seen in **Appendix E: Modified IMI-questionnaire** was used to find out the reception of the game by the users, what impact the added Kinect elements have and to find out if they think this game adds growth possibilities in ski training. Not all questions of the IMI were used (only Ineterst/Joy, Value/Usefulness for both the general application and the added elements). This first type of evaluation is done with the test subjects that played the game using a pro ski-simulator in the Smart XP, a location in the Zilverling on the University of Twente campus. Second, a semi-structured interview has been created to conduct on users that would test the application on an actual revolving slope, but due to setbacks this could not be realized. The outlines of the semi-structured interview can be found in **Appendix F: Outlines Semi-Structured Interview**.

4 IDEATION PHASE

Main Research Requirement Focus: *"How to create an augmented reality skiing application for on a portable slope where different types of hardware work together to* ***support the ski-learning process*** *?"*

The objective of the ideation phase is to obtain a concrete project idea that can fulfil the needs and requirements set by the target group. Firstly, the target group is identified together with other stakeholders in Chapter 4.1 by conducting an stakeholder analyses. Then, having identified the target group, several use cases are described in Chapter 4.2 to identify the way of working of the users. Afterwards, a brainstorm has been conducted to find different possible project ideas (Chapter 4.3). In Chapter 4.4, the different potential project ideas are discussed and explained. Finally, in chapter 4.5, the final project idea is described.

4.1 STAKEHOLDER ANALYSIS

As described in the Methodology section of this research, the stakeholder identification method of Sharp, Finkelstein, & Galal (1999) is applied. The stakeholders which are identified as 'baseline stakeholders' are displayed in **Table 4.1.** The table shows us that there are three users: People who practice skiing along ski enthusiasts, ski trainers/personal trainers and gym- and ski hall owners. The first mentioned is concluded to be the primary target of the product, thus making them the main target group. Since ski and personal trainers are users of the product and are expected to explain and demonstrate it, they are identified as secondary users. Finally, the ones influencing the purchase and affecting the introduction of the system are the tertiary users, which are in this case gym and ski hall owners.

In addition to the users, the baseline stakeholder identification also contains developers, legislators and decision-makers stakeholders. Although it is important to identify the needs and requirements of these other roles the main focus is on the identified target group, the users. In addition, further stakeholder identification like suppliers, clients and satellite stakeholders will not be identified because of this.

Role	Stakeholder
Users	*People practicing skiing/ski enthusiasts (primary)*
	Ski trainers/Personal trainers (secondary)
	Gym owners/Ski hall owners (tertiary)
Developers	*Programmers*
	Designers
	Maintenance Expert
	Developers of the ski slope
Legislators	*Government*
	Insurance companies
	Safety executives
Decision-makers	*Executive board/Management/CEO of distributor company*

Table 4.1. *Baseline stakeholders*

4.2 USE CASES

To concretize the interests of the target group two user cases were written based on the stakeholders analyses. The format of the use cases are based on Cockburn (2000) examples. Additionally, these user cases make use of the PACT method. These cases cover the needs of the users and show different scenarios regarding the product. The first case is a related to using the installation for the first time, whereas the second case focusses more on the motivational elements of the installation.

Use Case 1

Title	Using the installation for the first time.
Description	The user is going on a skiing holiday in the future, but wants to train his skiing abilities some more before going. He goes to a gym where this installation is located and asks a personal trainer to help him out.
Primary Actor	Amateur Skier
Preconditions	User wants to train his skiing abilities .
Postconditions	User has trained certain ski abilities and feels motivated.
PACT analysis	
People	Bjorn, an amateur skier, 23 years old, ski experience of 3 years, hasn't practiced skiing in half a year, wants to practice more before going on vacation. Zachery, a personal trainer at a gym, 28 years old, instructing expertise on gym installations and core training sessions.
Activities	Performing a ski training sessions with use of an AR game on a portable slope for the first time.
Context	The AR ski installation is located in a gym.
Technology	People who want to practice skiing use the portable ski slope with the AR game.
Main Success Scenario	1. Bjorn enters the Gym where the installation is located and talks to Zachery, the personal trainer, that is available. 2. Zachery explains how the system can be operated and helps Bjorn in the correct skiing gear. 3. When standing on the Ski Slope Zachery prepares the HMD and gives it to Bjorn. 4. Bjorn can ask final questions and Zachery will explain once again shortly what is going to happen. 5. Bjorn can now make a choice which type of training he wants to do. 6. After selecting the desired training Zachery will turn on the portable ski slope. 7. Then after a small habituation period the game will commence. 8. Bjorn will play the game that is linked to the desired training. 9. Zachery will give tips to train Bjorn even more. 10. When the game is finished Zachery will turn off the portable ski slope and give final tips to Bjorn. 11. Bjorn can now train another set of skills or do the same training again, whilst Zachery will go help other people.

	12. Bjorn either keeps on training or removes the HMD and to practice something else.
Extensions	2. If no personal trainer is present with knowledge of the system Bjorn may have to wait till there is one. 4. The game might not start due to technical difficulties. 11. When Zachery observes that Bjorn cannot exercise without supervision he can either choose to stay or to make him train something else.

Use Case 2

Title	Using the installation to beat a record on a specific game mode
Description	Some game modes in the AR skiing game have leaderboards included. The user found out that someone broke his record on the 'Follow the Trainer' game mode and is motivated to get the record back.
Primary Actor	Amateur Skier
Secondary Actor	Personal Trainer
Preconditions	User wants to beat the current record on a specific game mode.
Postconditions	The user leaves the installation satisfied after beating the previous record.
PACT analysis	
People	Martin, an amateur skier, 26 years old, goes skiing every year with his friends, always want to be the best in every context. Rosie, a personal trainer at a gym, 24 years old, expertise in core training sessions and Pilates courses.
Activities	Performing a ski training sessions with use of an AR game on a portable slope to beat a record.
Context	The AR ski installation is located in a gym.
Technology	People who want to practice skiing in the gym use the portable ski slope with the AR game.
Main Success Scenario	1. Martin visits the gym to start a training sessions with a friend of his. 2. He checks the leaderboards on the portable ski slope and finds out that his previous record on the game mode 'Follow the Trainer' has been broken by someone. 3. He becomes very motivated to regain his position as record holder. 4. He walks to Rosie, the personal trainer available, and asks her to set up the game. 5. Rosie gives Martin the gear and sets up the game mode. 6. Martin puts on the HMD and starts the game by using the voice commands. 7. Rosie, knowing how much experience Martin has, walks away to help other people. 8. Martin keeps on playing the game until he has broken the record. 9. After that he tries to do a different game mode on a harder level to train his skills.

	10. When finished he either calls Rosie or his friend to shut down the portable ski slope. 11. Martin removes the HMD and takes off the gear. 12. Martin shows his record to his friend and leaves the gym content.
Extensions	4. The personal trainer available is busy at the moment so he has to wait till she's done. 5. The game might not start due to technical difficulties. 6. Due to external factors, the voice commands might not work. 10. When no-one is coming the user has to keep waiting and keep skiing till someone can shut it off. 12. The leaderboards might not work due to technical difficulties.

4.3 BRAINSTORM

In this section important branches on the concept were explored during a brainstorm session. It was concluded that three topics should be explored: Level difficulty, use interfaces and hardware possibilities and requirements. Every topic shows a figure with the train of thought with at the end different ideas. These ideas are numbered in the figure and are discussed in the table underneath it.

4.3.1 Level Differentiation

This part of the brainstorm session was about the level differentiation. In **Figure 4.1**, the train of thought is visible. The most important step to get to the goal is to address the importance of motivation. In the State-of-the-Art section a research has been conducted to discuss motivation. By combining two motivational types (and corresponding motivational elements) six different types of level types have been thought of. In **Table 4.2** the explanations of all the level types is discussed.

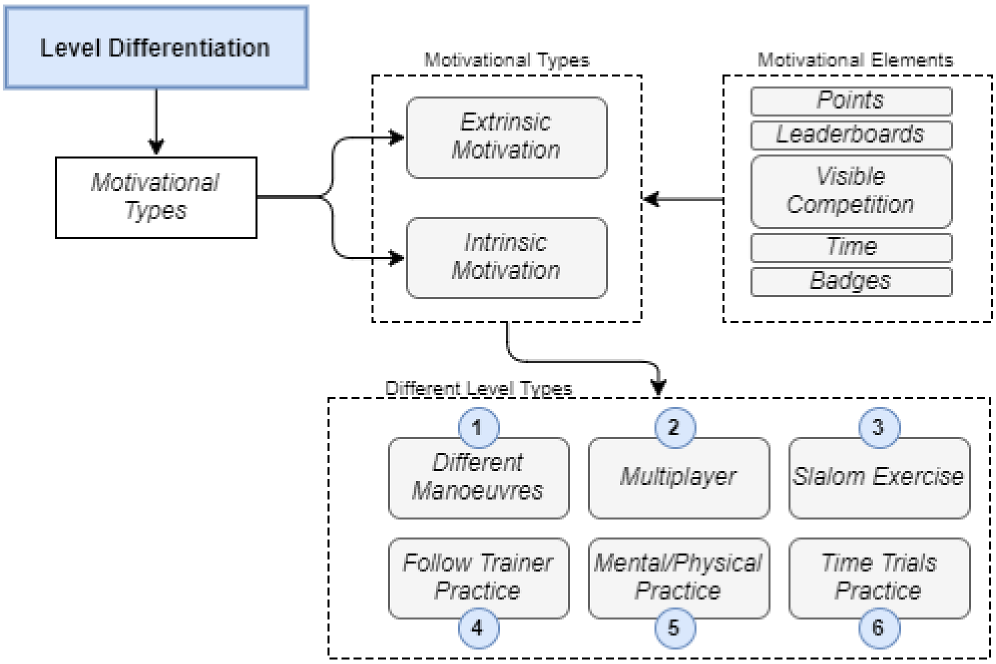


Figure 4.1. *Brainstorm train of thought on Level Differentiation*

Number	Explanation	Elements
1	Different Manoeuvres, the idea behind this game mode is that the player will be skiing down a slope and has to perform certain manoeuvres* to proceed in the race. These manoeuvres could be for example, having to make a sharp turn to the right/left, having to brake quickly to avoid collision, evade objects that will become visible very late. * *In discussion with a ski trainer other suitable manoeuvres could be explored.*	Time, Points
2	Multiplayer is known for making games more exiting and playable. As discussed in the State-of-the-Art review it is proven that multiplayer motivates players and makes the game less repetitive. The fact that it is constantly played against new players makes it more unpredictable. That in combination with the fact that people get motivated by competitiveness, might make this game mode utter attractive for our target group.	Visible Competition Points, Badges, Leaderboard
3	Slalom Exercise is a game mode that incorporates the classic ski routine. Gates shall be displayed for the player to ski through. The player shall obtain points and will compete with others in a semi-multiplayer environment (no direct multiplayer elements whilst playing, but compete against other players) though a leaderboard.	Points, Leaderboards
4	The Follow the Trainer exercise is that you’ll be following a character that will be visible in front of you. When skiing you’ll need to follow this character and mimic his movements. When successfully mimicking a movement*, you’ll be rewarded with points. * *Mimicking a movement can be a successful follow through a gate or successfully mimicking the stance of the trainer using a skeleton tracker*	Points, Leaderboards
5	Mental/Physical practice will make you solve mathematical equations* whilst skiing through gates. A sum shall be displayed on screen (which will not be irritating) and the player has to calculate the solution and ski through the gate that has the correct solution. Points shall be awarded. * *It does not have to be mathematical equations. It could also be another way players have to think about an solution.*	Points, Leaderboards
6	Time trials exercise is a race against the clock. This could also be a semi-multiplayer game mode where you can see a ghost, shadow of another contender on your display. Your goal is to finish the track as quick as possible. This could be done by collecting boost items that will be spawned along the track.	Time, Visible Competition

Table 4.2. *Level type explanation*

4.3.2 User Interfaces

Another important part of the product is the User Interfaces within the game. In **Figure 4.2**, the train of thought is visible of this section. It was important to differentiate between two different parts of the game: Menu and In-game. Both these elements have certain requirements. These requirements are explained in **Table 4.3.** The menu interfaces are visible when starting the game, and when pausing the game. Smaller interfaces, like addressing the option to ask for help and the text that you should follow the trainer, are visible during the duration of the game.

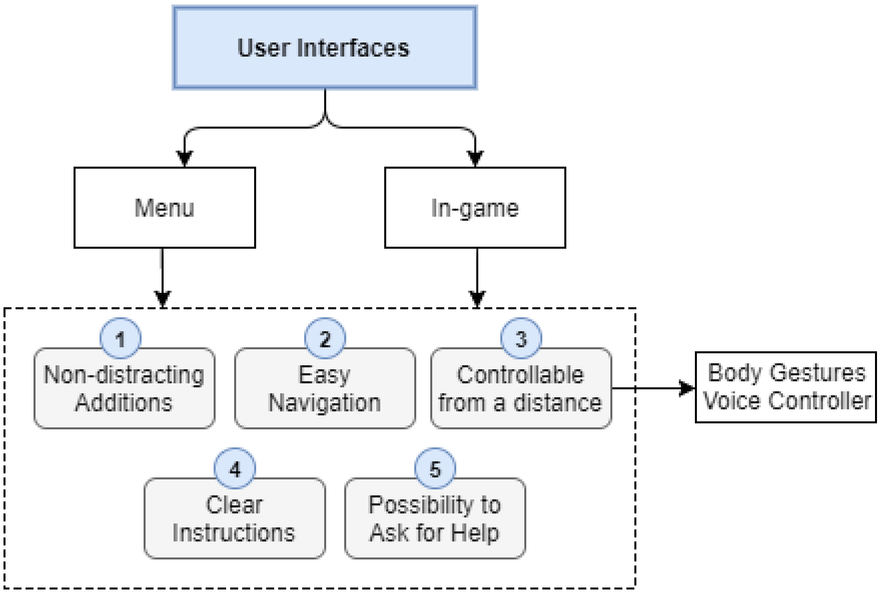


Figure 4.2. *Brainstorm train of thought on User Interfaces*

Number	State	Explanation
1	*Menu*	When looking through an HMD to your menu, it should be clear and non-distracting. Important factors are: crowdedness, soothing and irritation.
	In-Game	When motivational elements are used (e.g. timer, points counter, leaderboard) it should not be distracting and irritating during the game
2	*Menu*	Buttons should be clearly readable and understandable. The text that described the button should be recognizable and should not be confusing in any way. It should be clear how to navigate through the menu and people should be able to get stuck in a sub-menu.
	In-Game	When wanting to pause, continue, change level or change settings whilst in-game it should be a quick and easy action to undertake.
3	*Menu*	The buttons and options should be controllable from a distance, since you are not close to the pc when using the product. Voice controllers or hand gestures might be utilized to control the game. Both have clear positives and negatives. Voice controlling makes it possible to minimize the amount of buttons on the screen (positive), but makes you have to talk loudly in a room where others might be working too (negative). The hand gestures have the complete opposite.
	In-Game	When wanting to pause, continue, change level or change settings whilst in-game it should be a quick and easy action to undertake. Voice controller can

		be the best and quickest solution here, since hand gestures might be irritating to do whilst doing an exercise.
4	*Menu* *In-Game*	When using the voice controller or hand gestures it should clear what functionalities it can perform. It should be indicated what the options are and there should never be confusion about how to, for example, open a certain menu, how to lower the volume or how to pause the game.
5	*Menu* *In-Game*	There should be an option to click the Help button that displays exactly what every option does.

Table 4.3. *Explanation on the UI requirements*

4.3.3 Hardware possibilities and requirements

A big part of the research is about using different types of sensors/hardware. It has been identified that there are three important subjects that should be covered. These are: *Motion Detection*, *Location Determination* and *Visualization*. As part of the hardware connectivity it is important to include the *Product Platform* in this part. In **Figure 4.3** the train of thought can be seen and in **Table 4.4** explanations of both the sensor/hardware and the requirements can be seen.

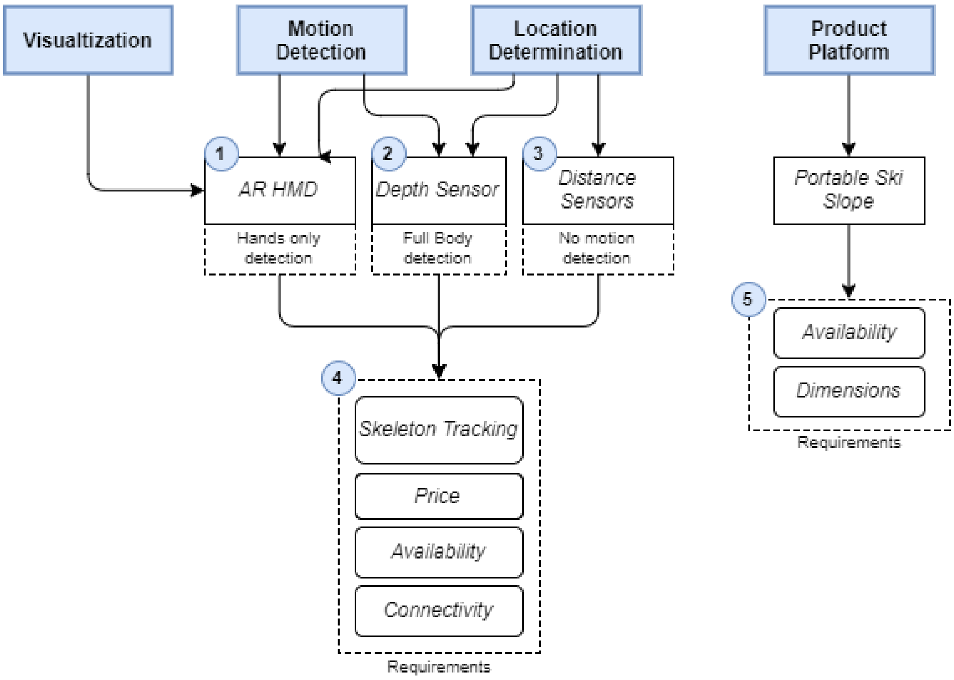


Figure 4.3. *Train of thought on the hardware possibilities and requirements*

Number	Explanation
1	An AR HMD is an Augmented Reality Head-Mounted Display. There are many different types on the market (see State-of-the-Art section). Some AR HMD's have possibilities to detect motions, but only hand gestures, which is not suitable enough for this project. Some types have the possibility to determinate the users location. Although not perfect for both motion detection and location determination it is key for displaying the game. Visualization is completely fulfilled through an acceptable AR HMD.

2	Depth sensors can detect full bodies. When looking at the Microsoft Kinect v2 for example, it has the ability to track six different skeletons of users at the same time. It can also easily determinate the location of the user.	
3	Distance sensors, like the HC-SR04, can locate the user on one axis. These sensors are able to locate the player on a track, but will have a lot of outliers.	
4	*Skeleton Tracking*	The complete circuit should be able to track the skeleton of the user. This can be used for a specific game mode and used for tracking the players motions to reflect on later.
	Price	A goal of this project is to do it cheaply. It is important that the complete circuit meets all requirements, but does it with cheap sensors/hardware.
	Availability	The sensors/hardware should be available and easy to obtain.
	Connectivity	All different sensors/hardware should be able to be connected with each other. They will be working together to form the complete project. For now a great intermediator is Unity 5.
5	*Availability*	The portable ski slope should be available.
	Dimensions	The dimensions of the portable ski slope should be in line with the motion detection and location determinations dimensions. All movements should be readable without big stutters.

Table 4.4. *Explanation on the hardware possibilities and requirements*

4.3.4 Complete overview of brainstorm

In Figure 4.4 the combination of all three brainstorm sessions can be seen.

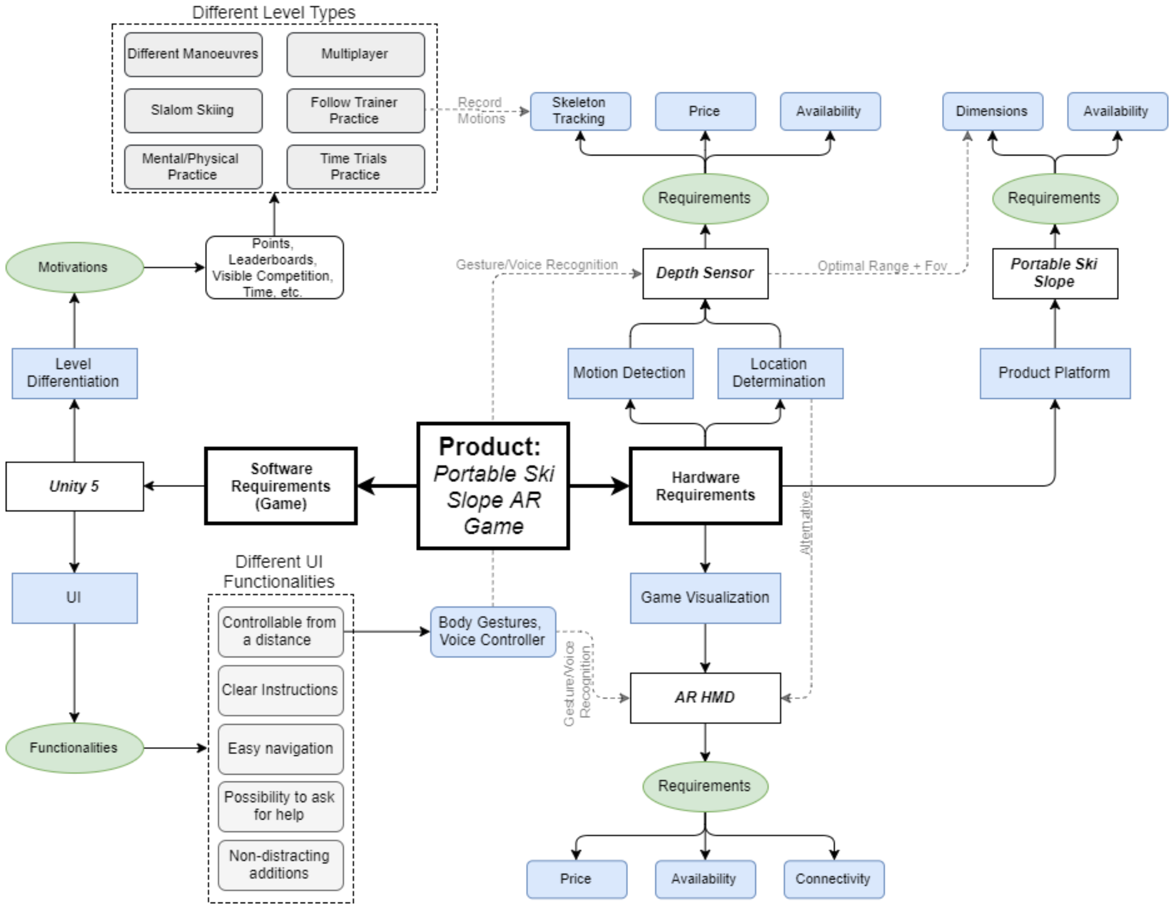


Figure 4.4. *Final brainstorm visualization*

4.4 Concept Ideas

By combining the brainstorm outcomes with the use cases several concept ideas can be created. First, four ideas are described below. These are based on both the user needs and the information found during the state of the art of this study. Second, these ideas are shortly evaluated. As a result of this evaluation, one idea is chosen to examine in this research.

4.4.1 Four Augmented Reality Concept Ideas

Motivation Selection (using HMD)

Ryan & Deci (2000) identified different types of extrinsic motivation in the OIT. In the accompanied taxonomy six different types are discussed. The levels of the motivational types can be tested by using the SMS-II (Pelletier et al., 2013). Using the results of this test it can be concluded what type of game give the player the most motivation. This, in combination with the identified learning style, (González-Haro, Calleja-González, & Escanero, 2010; i.e. accommodating, using other people's analysis and information to take a practical and experiential approach) will make the game modes motivational for the player. Each type of motivation will have a game mode dedicated to it. The process will be in the following steps:

- The player will fill in the SMS-II (which can be either on paper or online, the latter is optimal). The results of this test will notify the game which type of game mode the player will need to play to get optimal motivation.
- When the player is playing the game the recommended game mode will be the one based on the results of the test. Although the player has the option to choose another type of game mode, if he wants to, it is recommended to play the recommended game mode, since it will make it more fun and enjoyable and thus more motivational.

Motion Capture, position tracing, simple direct feedback and voice control (using Kinect v2 and HMD)

The depth sensor shall be used for multiple elements. The first element shall be the motion capturing of the movements of an advanced skier. The recorded movements shall be placed on a rigged 3D model of a skier. This model shall ski in front of the user to make the user mimic the model. Next, the depth sensor shall portray the skeleton of the user to create an direct feedback source. Lastly, the depth sensor shall measure the position of the user to make the expensive HoloLens obsolete. Lastly the depth sensor shall be used as microphone to make voice controls possible.

Advanced direct Skeleton Feedback (using Kinect v2 and HMD)

By tracking the players skeleton and displaying it in the top right corner, feedback can be given be the means of colours to show how the stance of the player is related to the optimal stance. The player will get visual feedback on what to change and what to keep. This would require a pre-programmed skeleton of a professional skier on which the skeleton of the player will be compared. . When outside the boundaries of error-acceptance it shall indicate the problem.

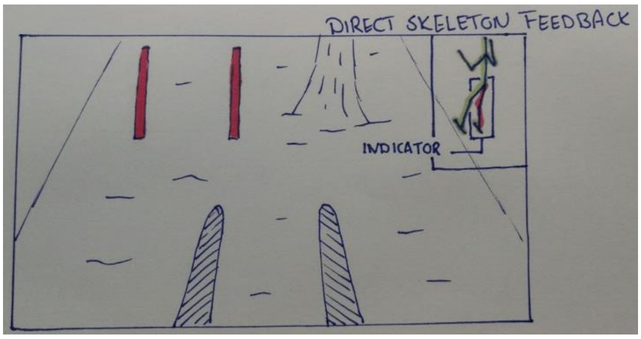


Figure 4.5. Direct Skeleton Feedback draft

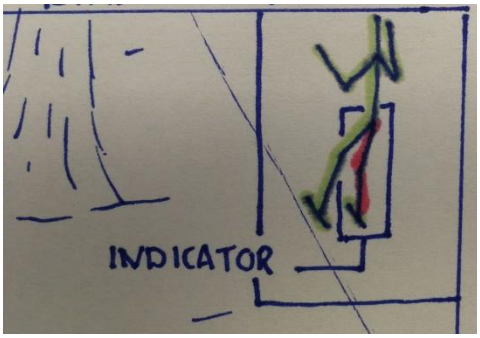


Figure 4.6. Indicator of the Direct Skeleton Feedback

Gym vs Gym multiplayer (using Kinect v2 and HMD)

When having multiple devices in different gym's a multiplayer game among all devices can be created. When standing on the portable ski slope you can see if:

- Another player in another gym is online and have the chance to invite him to a battle;
- There is a recent player which you can battle in a semi-multiplayer environment. As seen in Figure 4.7 you can see where the opponent has skied, whilst the opponent isn't actually skiing in real time. It will display a track of the other player on the ground.

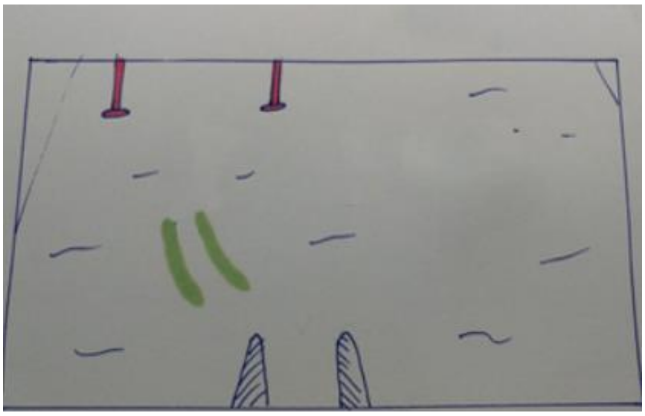


Figure 4.7 Interface for the application

It will mostly work on a point-based system, since you can't measure velocity (all ski slopes go with the same speed). When wanting to use time to clear the path the best way is to link it to a Kinect for Skeleton tracking to calculate speed by correct movement. The better the movements that faster you should go.

4.4.2 Evaluation of Concept Ideas

To get an insight in to the possibilities and opportunities of the four concept ideas, both the advantages and the disadvantages are discussed and displayed in **Table 4.5**. An overall score is given to each concept ideas by outweighing the disadvantages to the advantages. The evaluation is based on hypothetical situations that the ideas would be used for the revolving ski slope.

Concept Idea	Advantage	Disadvantage	Score
Motivation Selection	+ Makes the game more attractive to the players + Makes the players better, because of motivation to keep coming back.	- Other game modes might be less attractive - Players would have to fill in a form before playing the game, not everyone wants to do that.	0
Hardware/sensors selection for game making	+ Makes more elements possible, thus increasing attractiveness and learning possibilities + The UI Menu is important for the optimal playfulness (voice control is important) + Makes the players better, because of broad training options	- Usage of more hardware might make the setup harder to install	++
Advanced direct Skeleton Feedback	+ Will make players have a better stance and will improve their ski abilities	- Can be very distracting to players	0
Gym vs Gym Multiplayer	+ Multiplayer increases motivation to play the game, so more attractiveness		+

Table 4.5 Advantages and disadvantages of concept

4.5 PRODUCT IDEA

The product shall use the addition of the Kinect v2 to open up more possibilities for the skiing application. First, the depth sensor shall be used to motion capture the movements of an advanced skier on an simple skiing track. These movements shall be put on a rigged 3D model of a skier to act as an trainer. It will ski in front of the user and the goal is to follow him through the gates. Points can be gathered when the user skies through the correct gates. Second, the depth sensor shall track the movements of the user and display the skeleton in the corner to act as direct feedback for the user. Third, the depth sensor will track the users position on the track to make the HoloLens obsolete. By using another HMD instead of the expensive HoloLens (~ €3.000,-) the price for production will drastically drop. Lastly, an UI menu shall be created which can be controlled by using your voice.

5 SPECIFICATION PHASE

During the specification phase the design of the product will be discussed. This will be done by creating Lo-Fi- (i.e. paper prototype) and Hi-Fi prototypes (i.e. virtual prototype) and testing these with users. The feedback from these users will be used to refine the product and will be put into functional and non-functional requirements by using the MoSCoW technique (van Vliet, 2008). These requirements form the basis of the Realization phase.

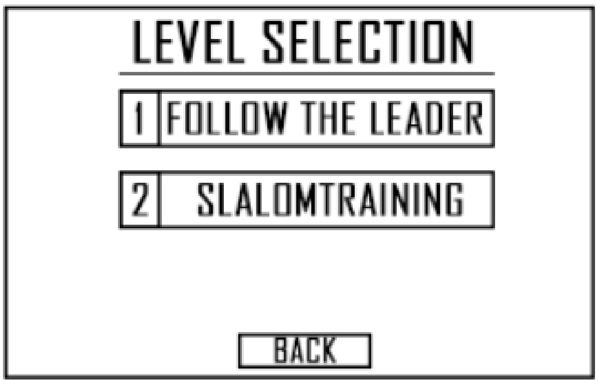
5.1 LO-FI PROTOTYPING CREATION AND TESTING

Based on the product idea presented in Chapter 4.5, a Lo-Fi prototype was made. This was done by creating a paper prototype. This paper prototype will display the functions the game possesses to concretize what the final product will look like. Below the prototype is displayed with explanation underneath every step. The symbol displays when a voice command is used.

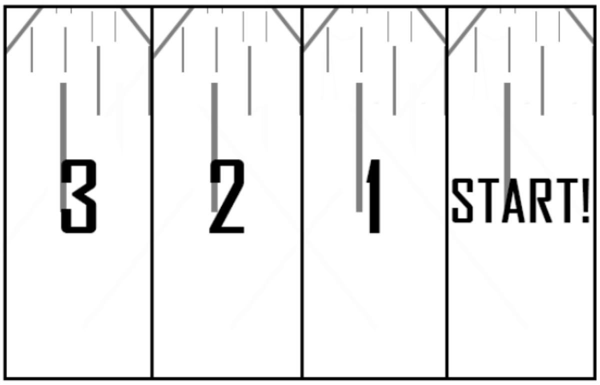
1: First, the player will be shown the main menu. This has three options: Start, Settings and Quit. The test “Use your voice to control the menu!” is displayed to let the user know that the way to use the menu is by using a voice

2: Settings - In the settings menu the user can adjust the audio levels. Using your voice you can say “on” and “off” to manage the audio. By saying back you can go back to the main menu.

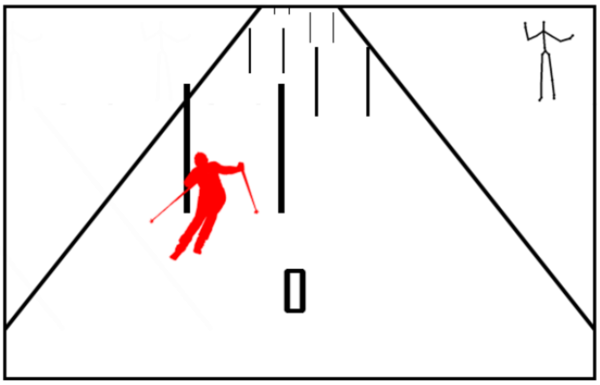
3: Back - Using the back command the main menu will open again. From here you can quit the game or start playing.



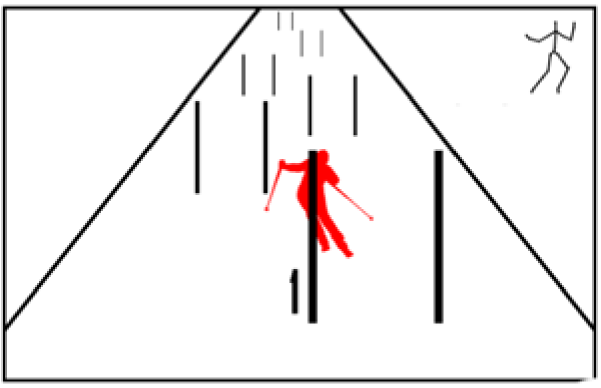
4: Start - In the Level Selection submenu two different levels will be shown: Follow the Leader and Slalom Training. But can be accessed by saying “Follow the Leader” and “Slalom Training”. These will open the corresponding game modes.



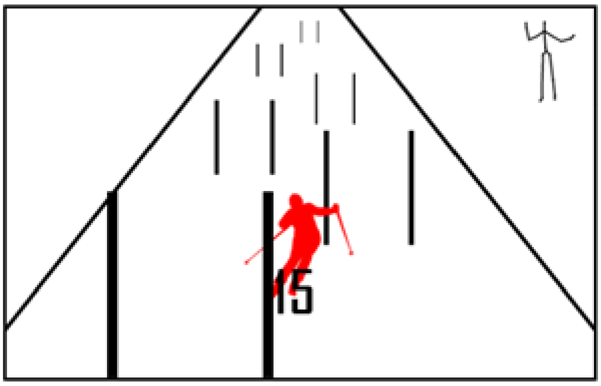
5: Follow The Leader / One - This game mode will firstly countdown from three to one and displays “Start!”. After this the game will commence.



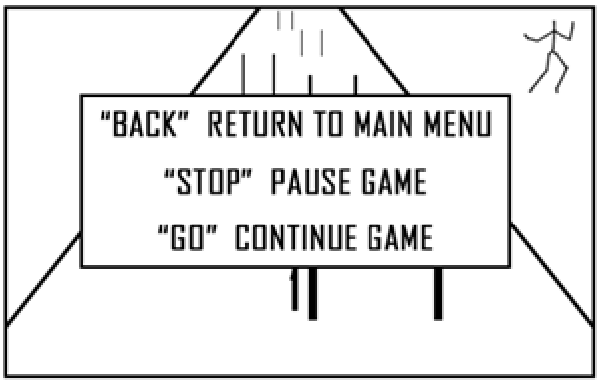
6: When the game commences it will display the track, the gates, a silhouette of someone skiing, points and the players skeleton in the top right corner. You have to follow the skier in front of you and go to the gates that he is skiing through. That’s how you get points.



7: You can check your skeleton for your movements. Possibly in the future it can recognize incorrect movements and will tell you what to change. This was not feasible during this project unfortunatly.



8: Gather as many points as you can. The game will speed up constantly and make it much harder for you to follow. The game will end when the user finds itself in a hopeless situation, or when the userf finds himself done.



9: Help - The Help menu will open with the commands to play the game. It shows you what kind of voice commands belong to what actions. This should be clear enough.

10: Back + Quit - By saying Back you will return to the Main Menu. By saying Quit you will exit the application.

This paper prototype was originally made on paper, but was recreated with Adobe Photoshop and printed on paper. This prototype has been tested with four users by play-testing the paper-prototype. By given them certain actions to perform, I could find out if the lay-out of the game was clear for the users. The users had to perform the following tasks:

- Go to Settings and turn off the sound.
- From the Settings Menu, go to and select the 'Slalom Training' game mode.
- Play the game for a while, then Pause the game and Restart the level.
- From the 'Slalom Training' game mode, go back to the Main Menu and close the application.

The users explained their thoughts on how easy it was to find each step. The feedback was gathered and can be seen in **Appendix G – Feedback Lo-Fi User Testing**. Although the overall feedback was positive there was one functionality that had to be addressed. All four didn’t know how to access the ‘Help’ command or that it even existed (step 9). In the virtual design a ‘Help’ button will be visible which will pause the game and display the functions: “Back”, “Stop” and “Go”.

5.2 HI-FI PROTOTYPE CREATION

After the input gained from the paper prototype a virtual Hi-Fi prototype was created. This was made using Unity5, which is a game development platform. First the menu was created, which can be controlled by your voice. The designs of the menu are kept simple with a black background, which is necessary to display it in AR. The menu is also kept the same, with the feedback processed, as in the Lo-Fi prototype, because the feedback stated that it is effective. Below the prototype is displayed with explanation underneath every step. The symbol displays when a voice command is used.

1: First, the player will be shown the main menu. This has three options: Start, Settings and Quit. The test “Use your voice to control the menu!” is displayed to let the user know that the way to use the menu is by using a voice

2: Settings - In the settings menu the user can adjust the audio levels. Using your voice you can say “on” and “off” to manage the audio. By saying back you can go back to the main menu.

3: Start - In the Level Selection submenu two different levels will be shown: Follow the Leader and Slalom Training. But can be accessed by saying “Follow the Leader” and “Slalom Training”. These will open the corresponding game modes.

5.3 PRODUCT REQUIREMENTS

No.	Requirements	Priority
R1	The product must contain an augmented reality environment that must be displayed on an AR HMD.	Must
R2	The product must contain a game which should be displayed on the AR HMD.	Must
R3	The game should contain gates the player must ski through	Must
R4.1	The product should contain a menu that contains the option to lower volume and let the user choose to start the game	Must
R4.2	The menu must be controllable via voice controllers	Should
R4.3	The menu must be able to be toggled on and off	Should
R5	The product must be able to track the players position using an depth sensor and sending the data to the AR HMD.	Must
R6	The product must display an interpretation of the users body, which will be used as direct feedback for the user.	Must
R7	The product must contain an animated model of a skier that shall lead the player through the course	Must
R8.1	The model should be animated by motion capturing an advanced skier using the depth sensor	Should
R8.2	The model should contain the looks of a skier	Should
R9	The game should contain a point based system that counts the points of the players	Should
R10	The game should contain a help function where voice commands are explained	Should
R11	The game should contain three-dimensional objects that will make the environment more alive (i.e. trees, rocks, snow)	Should
R12	The game could contain multiple gates on a line with a random path for the Motion Captured 3D model	Could
R13	The representation of the user could indicate what part of the movement should be adjusted	Could

R14	The game could contain a point system where points are scored when skiing through the correct gates	Could
R15	The game could contain sounds the make the game feel more alive	Could
R16	The movement of the character should be controlled by Kinect value instead of using the HoloLens positioning	Could
R17	The game won't contain multiple levels	Won't
R18	The game won't offer the possibility to raise or lower the difficulty	Won't
R19	The game shall not contain multiplayer elements	Won't

Table 5.1. *Product requirements*

R17, R18 and R19 are set on *won't*, not because they are bad additions to the end prototype, but because adding all of them could cause time issues. Also, they do not fall into the scope of the project, thus it was decided not to add them.

6 REALIZATION PHASE

In the realization phase the process of creating the game is described. First the system architecture is displayed and described how the system works. Second, test with the Kinect v2 have been conducted to find the most practical range to secure. Although this can be read in the product description of the Kinect, I want to check for myself which is the best distance to work with. After that the creation of the environment, motion capturing skiing movements and the creation of the direct feedback skeleton are described.

6.1 SKI PLATFORMS

During this project two different types of ski platforms are bound to be used. These are the Pro Ski-Simulator, which can be seen in **Figure 6.1**, located in the Smart XP, a section in the Zilverling on the University of Twente campus and a revolving ski slope, which can be seen in **Figure 6.2**. It was decided to do all the experiments on the revolving ski slope for the client, but this was not possible during the time frame of the project. The back-up platform, the Pro Ski-Simulator that could imitate the skiing slope in some way, was chosen to be used during the tests.

Figure 6.1. *Pro-Ski Simulator*

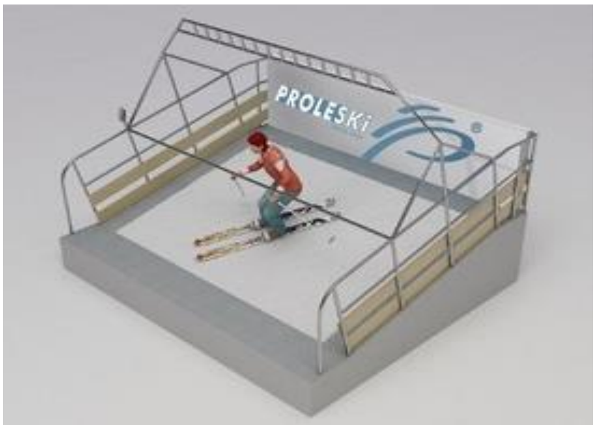


Figure 6.2. *Revolving Ski Slope*

6.2 DEPTH SENSOR TESTING

Since new hardware is being used (i.e. Microsoft Kinect V2), the microphone in the depth sensor will be used for registering the voice commands. That's why it was also used as microphone during the testing of this prototype. In the next section a research will be conducted to find out the following aspects concerning the Microsoft Kinect v2:

- **Optimal distance for *stable movement accuracy,*** which will be researched by looking at the skeleton whilst it's being tracked and looking for abnormal behaviour. Next to this, the colour of the skeleton will change to how obstructed the signal is (red = obstructed, green = tracked).
- **Optimal distance for *sufficient microphone reception***, which will be researched by testing the menu on different distances.

- **Optimal distance for *sufficient range***, which will be researched by calculations based on the distance (Field of View of the Kinect v2 is 70 degrees[9], thus tan 35.5 * distance to player * 2 = range).

The setup for this test can be seen in **Figure 6.5** (Outlined test setup) and **Figure 6.6** (Actual test setup). A ski warm up device was used to imitate movements made whilst skiing and was placed on four different distances. The depth sensor of choice was placed on two different heights to see if this variable matters and a monitor was placed to observe the skeleton tracking of the users body. The Kinect can see images that are between the distances of 1.5m and 3.0m. Therefore I want to find out what the best range for this project is. Four different distances where examined: 1.5m, 2.0m, 2.5m and 3.0m. Also the height of the Kinect will be changed to find the best setup. The choice fell between 0.8m and 1.0m.

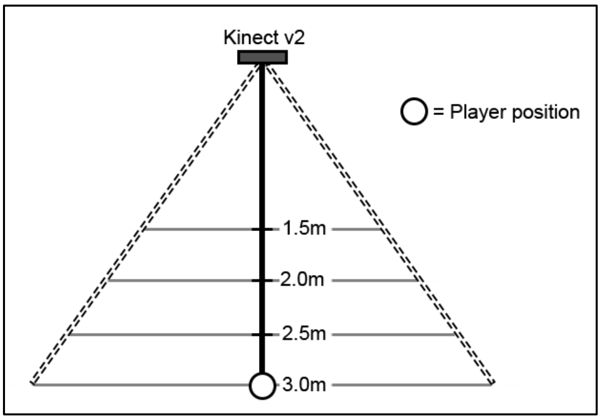


Fig 6.5. *Outlines test setup*

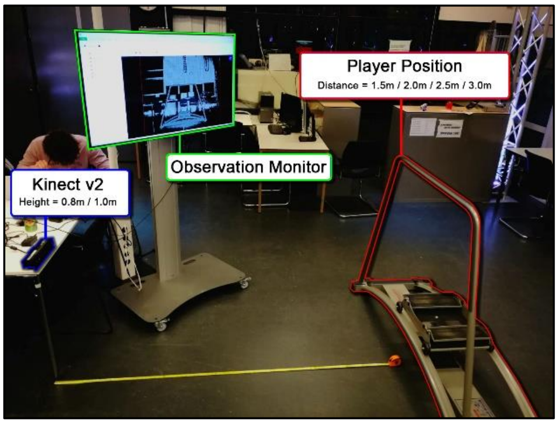


Fig 6.6. *Actual test setup*

6.2.1 Test 1: 1.5m x 0.8m and 1.5m x 1.0m.

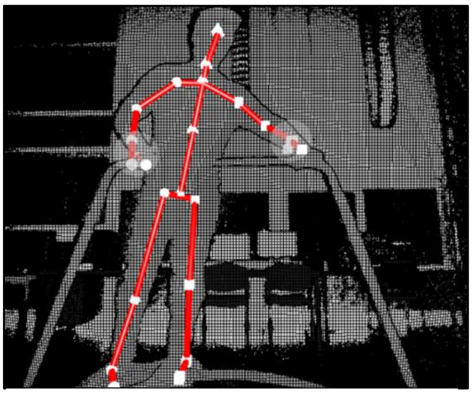


Figure 6.7. *Skeleton tracking at 1.5m*

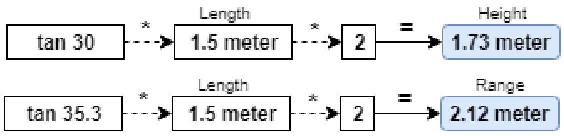
The first setup had the following measurements: 1.5m x 0.8m and 1.5m x 1.0m.

Movement accuracy: As can be seen from the color of the skeleton (red) the signal is obstructed, which makes it untrustworthy. Additionally, the feet and head joints of the skeleton are often falling out of frame, which produces false data. At a height of 0.8m, the head and feet joints of the skeleton tend to twitch. This will produce wrong data, making it too unreliable. At a height of 1.0m, the feet are more stable, but the head and feet joints still tend to fall out of frame. Therefor, this range is not suitable for accurate movement data.

[9] Source: http://123kinect.com/everything-kinect-2-one-place/43136/

Microphone Reception: The microphone picks up the voice commands easily. You don't have to yell, but you have to speak a little bit louder.

Range calculations: The ski slope has a width of 2.5 meters, which is more than the depth sensor can detect on this distance. Therefor, this distance is not suitable.



6.2.2 Test 2: 2.0m x 0.8m and 2.0m x 1.0m

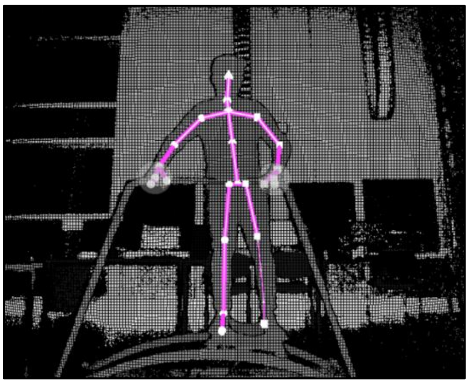


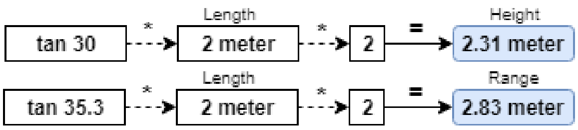
Figure 6.8. *Skeleton tracking at 205m*

The second setup had the following measurements: 2.0m x 0.8m and 2.0m x 1.0m

Movement accuracy: The skeleton displays a lightish pink color, which means that it has several obstructions, but overall sends data with sufficient quality. The skeleton has no twitches, except for the feet, which are tracked correctly on a height of 1.0m. When the depth sensor has its height set on 0.8m it will have problems with positioning the feet correctly, which causes twitches. This will cause wrong data. This range is suitable for accurate movement data, provided that the height of the depth sensor is at least 1.0m.

Microphone Reception: The microphone picks up the voice commands easily. You don't have to yell, but you have to speak a little bit louder.

Range calculations: The ski slope has a width of 2.5 meters, which is less than the depth sensor can detect on this distance. Therefor, this distance is suitable.



6.2.3 Test 3: 2.5m x 0.8m and 2.5m x 1.0m

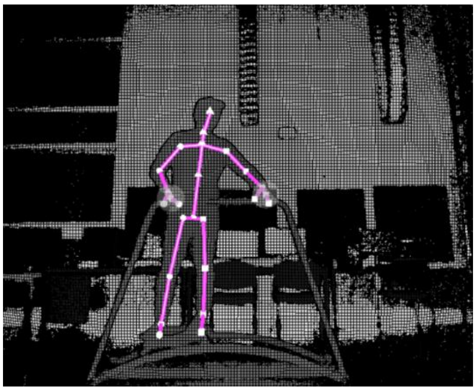


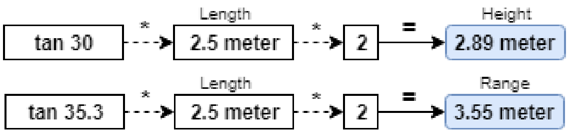
Figure 6.9. *Skeleton tracking at 2.5m*

The third setup had the following measurements: 2.5m x 0.8m and 2.5m x 1.0m

Movement accuracy: The difference between this distance (2.5m) and the 2.0m distance can barely be seen, when looking both at the colour of the skeleton and the stability of the skeleton on the monitor. It tracks the body steadily, but has trouble with the feet on a height of 0.8m, just as the one in the second setup. When the depth sensor has a height of 1.0m it tracks the feet correctly. This range is suitable for accurate movement data, provided that the height of the depth sensor is at least 1.0m.

Microphone Reception: The microphone picks up the voice commands. You don't have to yell, but you have to speak a little bit louder than with the first two setups.

Range calculations: The ski slope has a width of 2.5 meters, which is less than the depth sensor can detect on this distance. Therefor, this distance is suitable.



6.2.4 Test 4: 3.0m x 0.8m and 3.0m x 1.0m

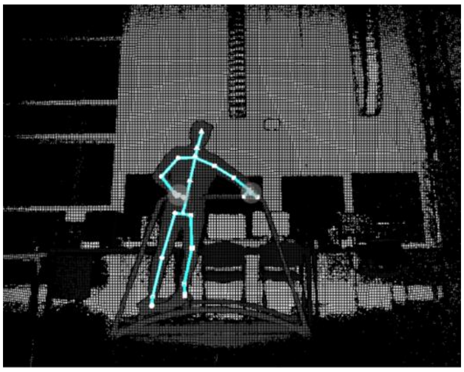


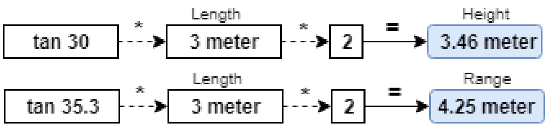
Figure 6.10. *Skeleton tracking at 3.0m*

The fourth setup had the following measurements: *3.0m x 0.8m and 3.0m x 1.0m*

Movement accuracy: Just as the second and third setup, this test does have stable results when looking on the monitor, but the color is light greenish. This means that it has the least obstructed signal of all distances. The joints at the feet get tracked better when it has a height of 1.0m, whilst the rest of the skeleton tracks perfectly. This range is suitable for accurate movement data, provided that the height of the depth sensor is at least 1.0m. This range provides the cleanest data of the four tests.

Microphone Reception: The microphone struggles to pick up the voice commands. You have to yell to make the voice commands work.

Range calculations: The ski slope has a width of 2.5 meters, which is less than the depth sensor can detect on this distance. Therefor, this distance is suitable.



6.2.5 Conclusion

The results from the four setups can be seen in **Table 6.1**. An overall score is given to each setup by outweighing the results of the three aspects. These scores are based on emotional observations. It can be seen that the fourth setup has the best movement accuracy and suitable range calculations, but has the worst microphone reception. The second setup is most suitable, thanks to its optimal range calculations and its optimal microphone reception. Although its movement accuracy is not the best of the setups it's still very accurate to produce trustworthy data. The conclusion of this test is that setup two is most suitable for this project.

Setup	Measurements	Movement Accuracy	Microphone Reception	Range Calculations	Suitability
1	1.5m x 0.8m/1.5m x 1.0m	-	++	-	Least suitable
2	2.0m x 0.8m/2.0m x 1.0m	+	++	++	Most suitable
3	2.5m x 0.8m/2.5m x 1.0m	+	+	++	-
4	3.0m x 0.8m/3.0m x 1.0m	++	-	++	-

Table 6.1. *Overview results depth sensor test*

6.3 GAME CREATION

Main Research Requirement Focus: "How to create an augmented reality ***skiing application*** *for on a portable slope where different types of hardware work together to support the ski-learning process ?"*

6.3.1 Game Environment

Using Unity5 an environment was built to create a semi-realistic skiing environment. It was decided to add extra features to make the environment feel more realistic and to replicate the feeling of skiing on an actual slope. Several objects where added to the scenery.

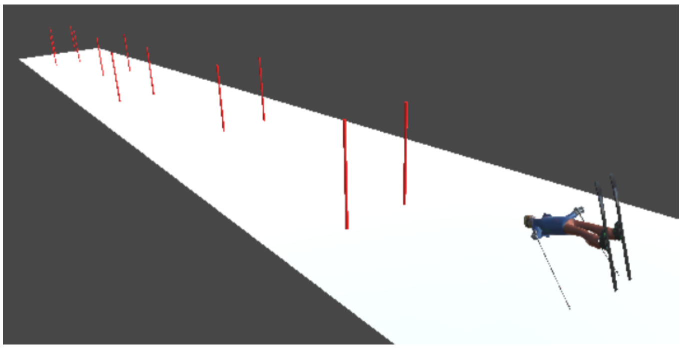


Figure 6.11. *Gates, plane and model in Environment*

First, the course was created along with the model of a skier. The gates were added and contain a script that makes them move forward to the player. After they have passed the camera they will be respawned at the end of the course to create an infinite loop of gates. It was chosen to only move the gates to lower the amount of processing power required. The plane on which the gates are located is made a specific size. This is done, because the HoloLens has a restricted field of view. The course is completely visible within this region, whilst still feeling natural. When playing the game the player will return to it's natural state, before that it has a 90 degree flip. This because of his render settings during the rendering process.

Figure 6.12. *UI Menu and background sound in Environment*

Second, the menu was created with all it's menus and options. Other than the Hi-Fi prototype described in Chapter 5.2 it was chosen not to use different scenes, but to enable and disable Game Objects when using a voice command. Also, it was chosen not to add the Level Selection menu, since this game only contains one game mode. The menu was placed at a distance 2.5 meter, which makes it clearly visible and easy to read. In **Figure 6.12** it can be seen that the canvas contain many different objects. It contains the Main Menu and the Settings Menu (where the audio can be turned on and off) and is completely voice controllable. Other than the menu a soundtrack was added, which contains the sound of a blizzard. This will make the game feel more alive. Lastly, a help menu was added which can be opened during the game. This will pause the game and gives you the possibility to read the voice commands that can be used during the game.

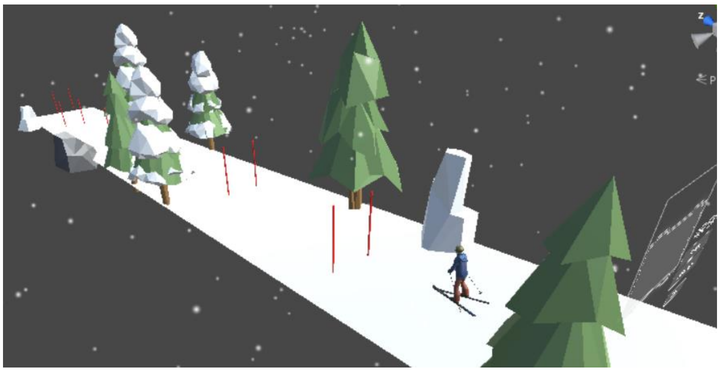


Figure 6.13. *Scenery and snow particles in Environment*

Third, the scenery was added to make the environment become more alive. Using free assets of the Unity Asset Store several Game Objects where placed into the environment. Prefabs of Game Objects by *Low Poly Styled Rocks by Daniel Robnik*[10] and *Snowy Low Poly Trees by False Wisp Studio*[11] were placed into the scenery. These objects are made children of the gate objects to make them move with them. Next, particles where placed into the environment to replicate snow. The particles are pushed towards the camera to make the illusion that the user is skiing through the snow.

The environment is being controlled by two scripts. One is used to make the gates along with its children objects move and respawn and the second one is used control the voice commands and its actions.

Now that the environment is created the next part is to add the skiing animation to the 3D model.

[10] Low Poly Styled Rocks by Daniel Robnik: https://www.assetstore.unity3d.com/en/#!/content/43486
[11] Snowy Low Poly Trees by False Wisp Studio: https://www.assetstore.unity3d.com/en/#!/content/76796

A few features were added to make the application more playable. At the main menu a text is displayed explaining that the user can use its voice to control the menu and the game. Also the trainer in the gate has text above it indicating that the user should follow the motion captured trainer. In **Figure 6.14** and **Figure 6.15** the game as seen from the HoloLens is shown.

Figure 6.14. *Menu seen as from the HoloLens*

Figure 6.15. *Application as from the HoloLens*

6.3.2 Motion Captured Trainer

The first usage of the depth sensor is the motion captured trainer. This trainer will contain an animation that contains the skiing movements. For this part an Unity assest was purchased, which is the Kinect Motion Capture Asset called "Cinema Mocap 2 - Markerless Motion Capture". Using this asset the movements of the skier could be captured. **Figure 6.16** shows the interface of the asset with the settings that where used for this project. In **Figure 6.17** the rigged 3D model of a skier can be seen.

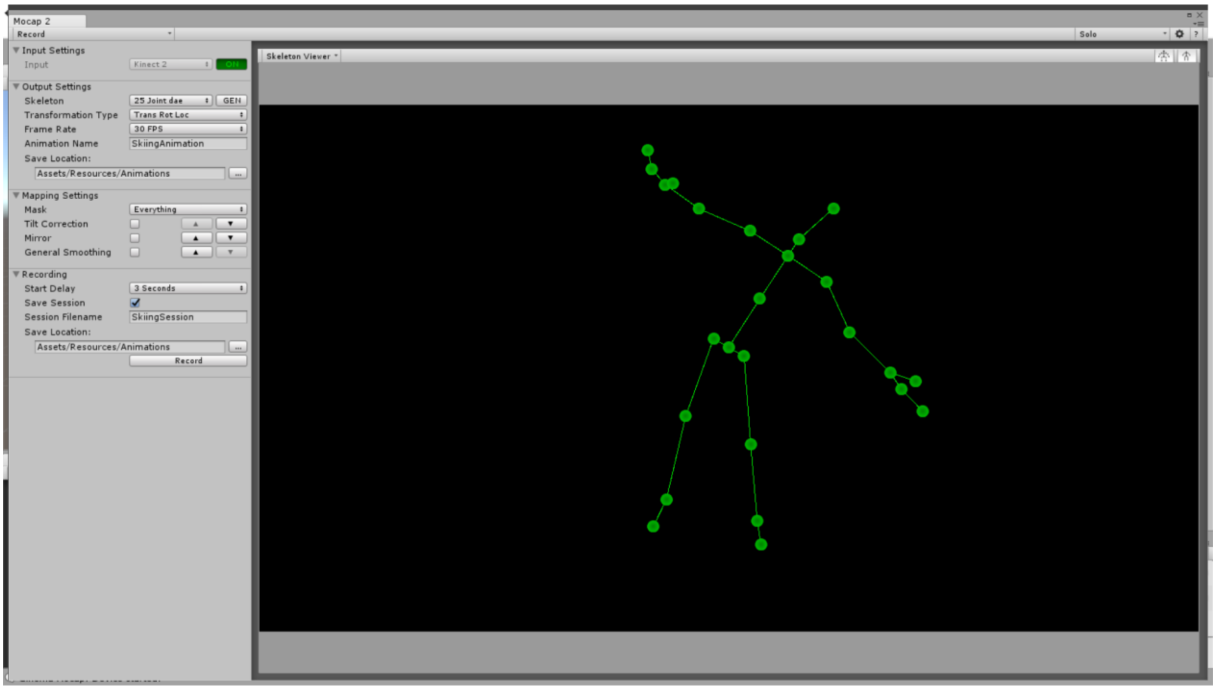


Figure 6.16. *Interface of the Motion Capture asset*

The *Tilt Correction* and *General Smoothing* were not used as it did not seem to make a visual difference. When pressing record the movements of the user can be captured as its going through the course. When saved it will create an .FBX file containing the animation, which can be given to the rigged 3D model of a skier, which can be seen in **Figure 6.17**. A model of a skier was chosen to make the scenery as realistic as possible. The animation will be loaded into the game when the player starts the game. The player must follow the skier through the different gates.

Figure 6.17. *Rigged 3D model of a skier used in the project*

Although the movements of the model are generally smooth, there are visual stutters in the movements. The model was designed in such a way that the ski poles are attached to the hands joint. So a minimal stutter in the hand movements, not visible, will result into an unrealistic and visible movement of the ski poles. Also the movement of the feet contains stutters, since it's not tracked optimally. When using the ski simulator the Kinect has some issues with tracking this joint perfectly for the entire duration of the movement. Since the skis are also connected to the feet joints, the smallest error in the feet joint results into an unrealistic and visible movement of the ski's. Apart from these errors, the movements look sufficient and can be used in the final game.

To make the game playable for a longer amount of time the animation is looped in such a way that the transition is perfect. This is done to make sure that the game will not end at a fixed time and that it takes in less space. Since the animation takes 4.3MB of space, whilst its duration is only 53 seconds, it should be a waste of space to make a complete animation of three minutes.

6.3.3 Direct feedback skeleton

As could be seen in **Figure 6.3** the Kinect collects data of the user and sends it to the scene on the HoloLens. Using several scripts data is first gathered in the *BodySourceManager* script. The data is then used by two other scripts. The first one is the *AvatarSourceView* script. What this does is creating a preview in your Unity window. This is useful, because it makes sure you don't have to deploy the game on the HoloLens each time to find out if the new updates work. The other script that gets the data is the *CustomMessages2* script. This allows sending body data as custom messages to the HoloLens. It sends

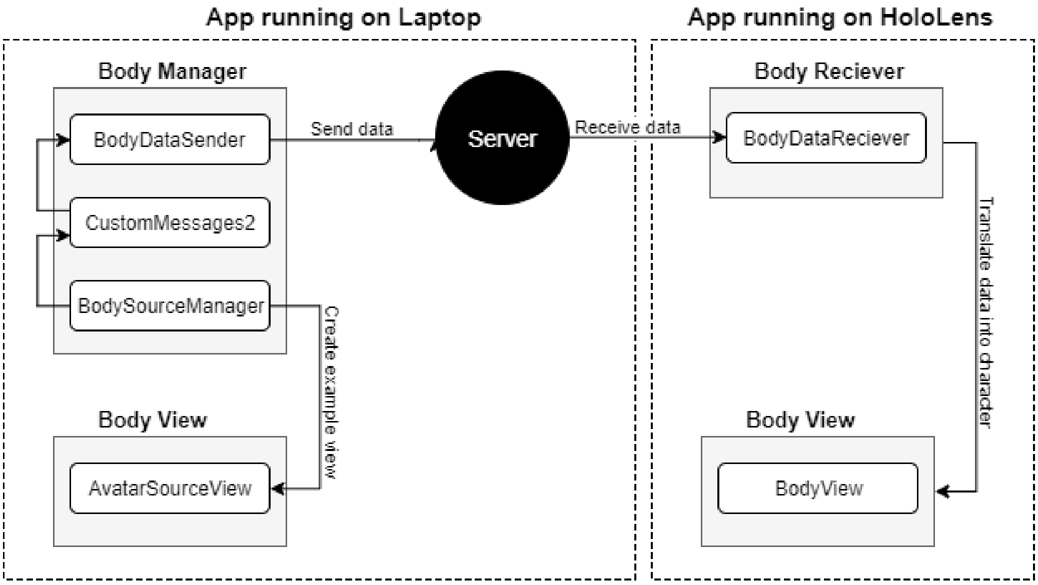


Figure 6.18. *Scripts architecture*

body data in the form of the tracking ID and then each joint's Vector3 coordinate. These are then used by the *BodyDataSender* to Send over the body data one tracked body at a time. On the deployed app on the HoloLens two scripts are active: *BodyDataReciever* which, as the name says, receives the data that was send to the server. Then the *BodyView* script translates these coordinates of the joints into the joints of a rigged 3D model to let the model moves as the user does. In **Figure 6.18** the full corporation between scripts can be seen.

The current version shows an model of a zombie, which is not ideal. The goal was to show lines of the bones instead, but after three weeks of trying everything it did not work. Therefore, this model shall be used during testing, because it has the functionality that the project desires, but not the ideal graphics. **Figure 6.19** shows the model in the screen.

Figure 6.19. *Model position and looks for the direct feedback skeleton*

This representation of the users active movements is visible in the top middle of the game. It was first thought of placing it in the corner, but then the objects (i.e. trees, rocks) will block the view. This is unpleasant for the user. When placing it in the middle it will not interfere with these objects and gives it a clear view.

The character moves like the user but some small errors do arise, but these do not hinder the usefulness and the playability of the game. First, when the user get out of frame (which should not happen) the model will freeze in frame, whilst another *new* model appears when coming back into frame. Second, the model sometimes stutters when performing movements. This is due to the Kinect not always able to register the joint positions optimally on every frame.

6.4 System Architecture

In this section the architecture of the system is explained. In here it can be seen how the system works together to make the game possible. All inputs and outputs are visible and each element is indicated by a number. The system contains out of six components: an advanced skier, the player, the Microsoft Kinect v2, the Microsoft HoloLens, Unity/Game and the server. The way they are working together can be seen in **Figure 6.3**. The numbers contain the following elements:

1. *The motion capture part;*
2. *The direct feedback skeleton part;*
3. *The position tracking part.*

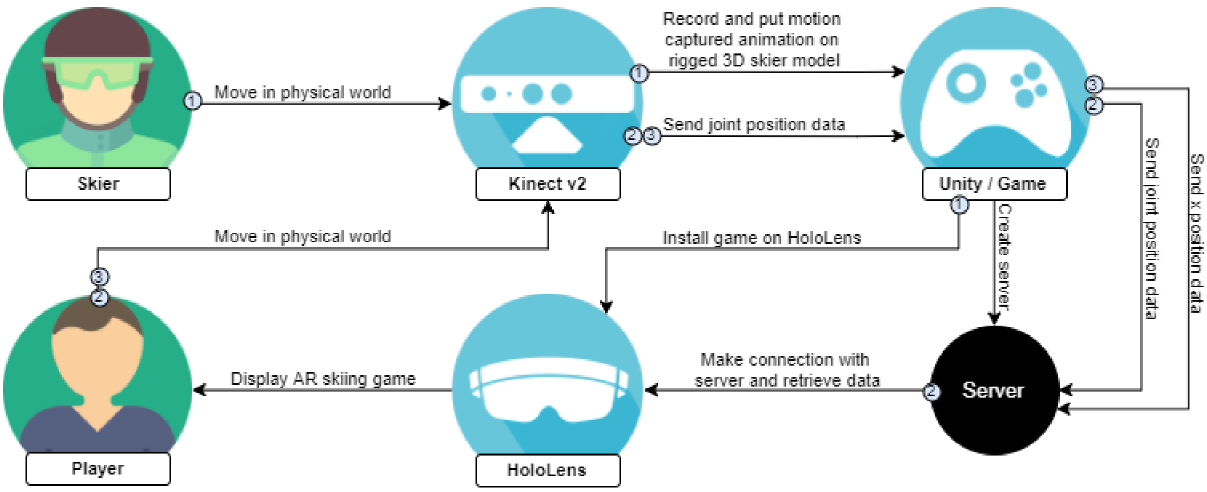
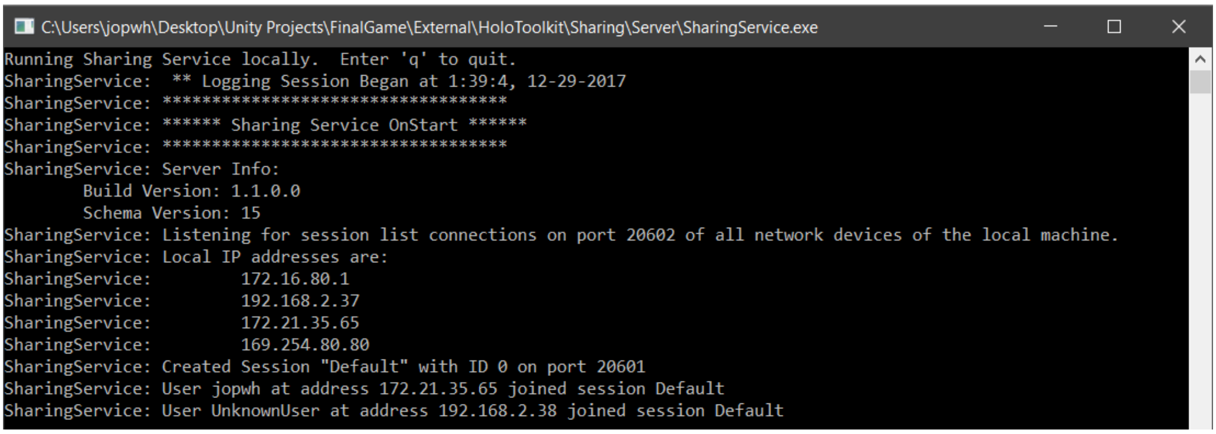


Figure 6.3. *System architecture*

The player moves in the physical world which is being tracked by the Kinect v2. The data gathered is automatically send to the Unity scene. Using the Sharing Service component on the HoloToolkit SDK in the scene we can open a server[12]. When running the 'Tx' scene, containing the *"BodyDataSender"* and *"CustomMessages2"* scripts the data will be send to the server [13]. When the game is already installed on the HoloLens, which we made an in depth tutorial for (**Appendix E: Tutorial settings up an AR environments on the HoloLens using Unity**), you can open the game and it will automatically join the server. This, however, is only the case when both devices are on the same internet connection. The server log will show information that can be seen in **Figure 6.4.** You can see that both the scene on Unity is connected to the server, containing the Kinect data, and that the HoloLens is also connected to receive the data.



```
C:\Users\jopwh\Desktop\Unity Projects\FinalGame\External\HoloToolkit\Sharing\Server\SharingService.exe
Running Sharing Service locally.  Enter 'q' to quit.
SharingService:  ** Logging Session Began at 1:39:4, 12-29-2017
SharingService: ***********************************
SharingService: ****** Sharing Service OnStart ******
SharingService: ***********************************
SharingService: Server Info:
        Build Version: 1.1.0.0
        Schema Version: 15
SharingService: Listening for session list connections on port 20602 of all network devices of the local machine.
SharingService: Local IP addresses are:
SharingService:         172.16.80.1
SharingService:         192.168.2.37
SharingService:         172.21.35.65
SharingService:         169.254.80.80
SharingService: Created Session "Default" with ID 0 on port 20601
SharingService: User jopwh at address 172.21.35.65 joined session Default
SharingService: User UnknownUser at address 192.168.2.38 joined session Default
```

Figure 6.4. *Log of the Sharing Service*

[12] Using the HoloToolKit by Microsoft: https://developer.microsoft.com/en-us/windows/mixed-reality/install_the_tools
[13] Using the tutorial and scenes by Project Infrared: https://hololens.reality.news/how-to/add-full-body-motion-tracking-hololens-with-kinect-0174419/

7 EVALUATION PHASE

In the evaluation phase the functional analysis will be checked if all the requirements are met. After that the experiments will be discussed. The experiments will be explained and the assessment is also discussed.

7.1 FUNCTIONAL ANALYSIS

In Chapter 5.4 product requirements were created to specify the outlines of the final product. These requirements were used to create product specified in Chapter 6. In **Table 7.1** these product requirements will be checked to find out if the final product meets these requirements.

No.	Requirements	Priority	Fulfilled
R1	The product must contain an augmented reality environment that must be displayed on an AR HMD.	*Must*	Yes
R2	The product must contain a game which should be displayed on the AR HMD.	*Must*	Yes
R3	The game should contain gates the player must ski through	*Must*	Yes
R4.1	The product should contain a menu that contains the option to lower volume and let the user choose to start the game	*Must*	Yes
R4.2	The menu must be controllable via voice controllers	*Should*	Yes
R4.3	The menu must be able to be toggled on and off	*Should*	Yes
R5	The product must be able to track the players position using an depth sensor and sending the data to the AR HMD.	*Must*	No
R6	The product must display an interpretation of the users body, which will be used as direct feedback for the user.	*Must*	Yes
R7	The product must contain an animated model of a skier that shall lead the player through the course.	*Must*	Yes
R8.1	The model should be animated by motion capturing an advanced skier using the depth sensor.	*Should*	Yes
R8.2	The model should contain the looks of a skier .	*Should*	Yes
R9	The game should contain a point based system that counts the points of the players.	*Should*	Partially
R10	The game should contain a help function where voice commands are explained.	*Should*	Yes
R11	The game should contain three-dimensional objects that will make the environment more alive (i.e. trees, rocks, snow).	*Should*	Yes

R12	The game could contain multiple gates on a line with a random path for the Motion Captured 3D model.	*Could*	No
R13	The representation of the user could indicate what part of the movement should be adjusted during the training.	*Could*	No
R14	The game could contain extra ways to obtain points (i.e. coins to pick up, successfully evaded an obstacle).	*Could*	No
R15	The game could contain sounds the make the game feel more alive.	*Could*	Yes
R16	The movement of the character should be controlled by Kinect value instead of using the HoloLens positioning.	*Could*	No
R17	The game won't contain multiple levels.	*Won't*	
R18	The game won't offer the possibility to raise or lower the difficulty.	*Won't*	
R19	The game shall not contain multiplayer elements.	*Won't*	

Table 7.1. *Product requirements with its assessments*

The functional analysis concludes that all **Must Have Requirements** are fulfilled with the exception of one requirement. The *'The product must be able to track the players position using an depth sensor and sending the data to the AR HMD.'*-requirement was not fully completed. This is simply because I couldn't get it to work. Many hours have been put into this sole requirement, but unfortunately it was not completely fulfilled. Although this would have benefitted the game it would have serious downsides. There is a big possibility that the movements would suffer from lag issues. The game would be less smooth and harder to play. This observation is based on the Direct Feedback Skeleton. It's visible that this character has a small delay.

The **Should Have Requirements** are also met with the exception of the *'The game should contain a point based system that counts the points of the players.'*-requirement. This requirement was based on R5, which is not fulfilled. Several ideas to work around this requirement did not work, unfortunately. For example, it was tried to link an object with a RigidBody as a child of the Camera position, which did not work. The gates, however, do possess a trigger that will add points to an score text. It was tested outside of the HoloLens and it worked perfectly. When R5 is fulfilled this score should be working soon after, but due time restraints this is not feasible.

The **Could Have Requirements** are not entirely fulfilled. One requirement is implemented into the game, which contains the audio requirements. Sounds of a blizzard storm are being heard while playing the game. This was a quick requirements to make, but with a lot of added effect to the feeling of the game.

7.2 USER EVALUATION

7.2.1 Evaluation Plan

This research focusses on both a qualitative and a quantitative approach. Therefore, the participants were selected based on some requirements. The target audience are people who are familiar with skiing and have experience in skiing in general. First, the decision for the participant of the evaluation is described followed the test set-up. Each topic is divided into two categories: tests done with the Pro Ski-Simulator and tests done with an Ski Slope. Different types of tests were conducted when using either the Pro Ski-Simulator of the Ski Slope. The participants using the Pro Ski-Simulator were presented the customized IMI-test along with a few open questions and have both a quantitative and qualitative approach. These tests take around 10 minutes per participant. The participants using the Ski Slope were presented a structured interview. These tests have the qualitative approach and take around half an hour.

7.2.1.1 Participants

Pro Ski-Simulator tests: The participants for these tests were chosen randomly. Asking people if they wanted to perform an experiment for me was feasible and also many friends of mine are leisure skiers. There were certain qualifications necessary for someone to perform the experiment. The participant should have skiing experience and familiar with feel of skiing indoors/outdoors. 10 participant were tested for this part of the evaluation. All participant were leisure skiers.

Ski Slope tests: Only a few participants were needed for this test. These participant are found by looking into my inner circle of friends and finding the most qualified individuals for the experiment. The participants selected have many years of experience and go on skiing vacations regularly. They are perfectly qualified subjects.

7.2.1.2 Experiment set-ups

Pro Ski-Simulator tests: The theoretical set-up can be seen in **Figure 7.1**, the actual set-up in use can be seen in **Figure 7.2** and **Figure 7.3**.

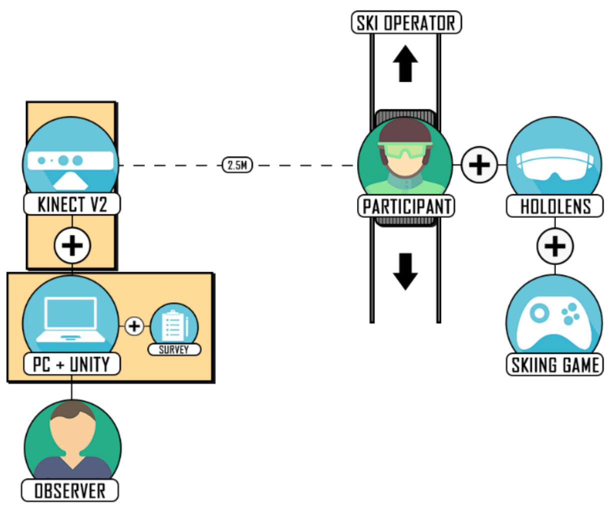


Figure 7.1. *Set-up for test with Pro Ski-Simulator*

First the participant received a small explanation about what the test is about. He will then take place on the Pro Ski-Simulator and put on the HoloLens. Before starting I will check on the computer if the body is checked correctly. Then, by using the voice commands the subject can start the application and try it out. After five minutes of trying out the application the subject will be asked to fill in the survey on the

Figure 7.2. *Participant playing the game*

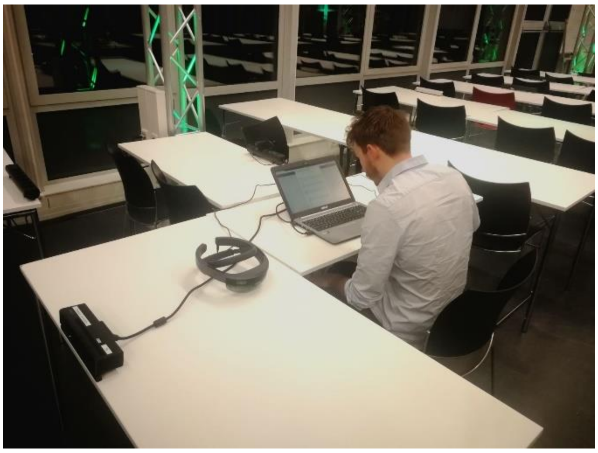


Figure 7.3. *Participant filling in the survey*

Revolving Ski Slope tests: The set-up can be seen in **Figure 7.4**

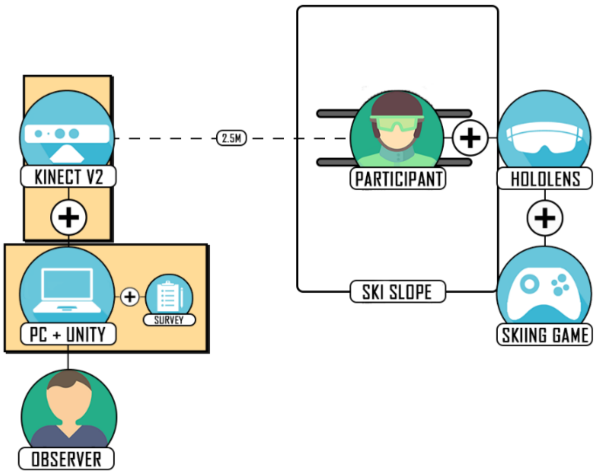


Figure 7.4. *Set-up for test with revolving Ski Slope*

First the participant received a small explanation about what the test is about. He will then take place on the revolving ski slope and put on the HoloLens. Before starting I will check on the computer if the body is checked correctly. Then, by using the voice commands the subject can start the application and try it out. After around ten minutes of trying out the application I will ask the subject to fill in the survey. After this I will start a recording application and start the structured interview.

7.3 Results

Experiments were only conducted on the Pro Ski-Simulator, due to setbacks and no possibility to use an actual revolving ski slope. Therefore only the first setup was used.

The modified survey consisted out of two elements of the IMI (Interest/Joy, Value/Usefulness on the game in general and Value/Usefulness off the Kinect elements) on three different topics and two open question at the end. The open question concern gives the users the opportunity to enlighten their choice. The full survey can be found in **Appendix J – Test Questionnaire**. The users were given a statement and they had to indicate their opinion based on a seven point scale, where 1 = not true at all, 4 = somewhat true and 7 = very true.

7.3.1 Interest/Joy Evaluation

The first topic concerned the interest and joy of the users regarding the application in general. The results of this first topic can be seen in **Figure 7.5**. The average of all results is given per statement along with its standard deviation, which is indicated by the brackets at the end.

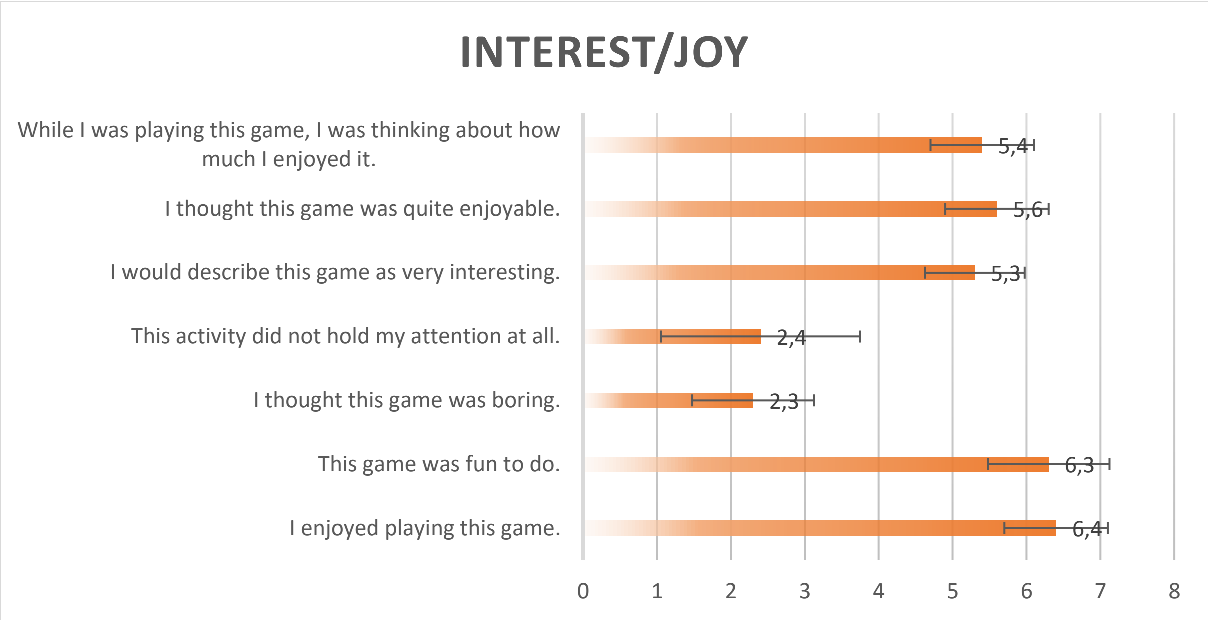


Figure 7.5. *Results of the Interest/Joy in General topic. Shown are the means and the standard deviations.*

What can be seen from the graph is that almost everyone enjoyed playing the game and found that the game was fun to do. Both statements have an average of around 6.4 and 6.3 respectively. The general opinion of the game was also that it was not boring and did hold the users attention. One remark on the latter is that the standard deviation is quite large, meaning that a few people indicated that this statement was somewhat true, whilst others indicated that this was not true. This was later explained by the fact that there was no game element like points, which would make the game more interesting. The general opinion on the interest and joy obtained by playing the application is that they enjoy playing the game. *The average mean of this topic is: 5.5.*

7.3.2 The Application as a Ski-Learning Game Evaluation

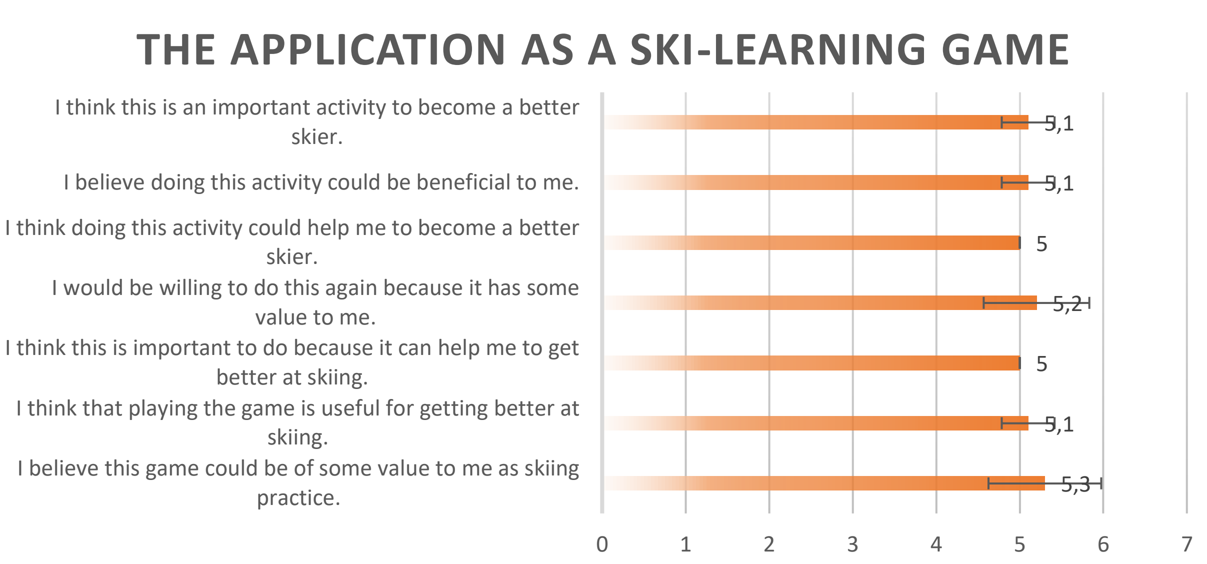


Figure 7.6. *Results of the application as a ski-learning game topic. Shown are the means and the standard deviations.*

The second topic concerns the impact of the application of the ski-learning process. As can be seen in **Figure 7.6**, it is noticeable that all statements have a mean between a 5.0 and a 5.3. This means that the users indicate that the application does have an impact on the ski-learning process, but that it is not optimal. Reading the open question it becomes clear that people find that the application should contain a point based system to make it more entertaining for a longer period of time. This has been one of the requirements, but unfortunately this requirement was not fulfilled due to time constraints. This, however, could be implemented in a new version of the application. *The average mean of this topic is: 5.1.*

It was expected that the general mean of this topic would be around this value, because this test has been conducted on the Pro Ski-Simulator, which does not fully cover the skiing experience. It is merely a device for warming- and strengthen up the muscles. However, by presenting these statements it was interesting to see if the game could turn this warmup device into an device that could enhance the users skiing abilities.

7.3.3 Kinect Elements as Ski-Learning Elements

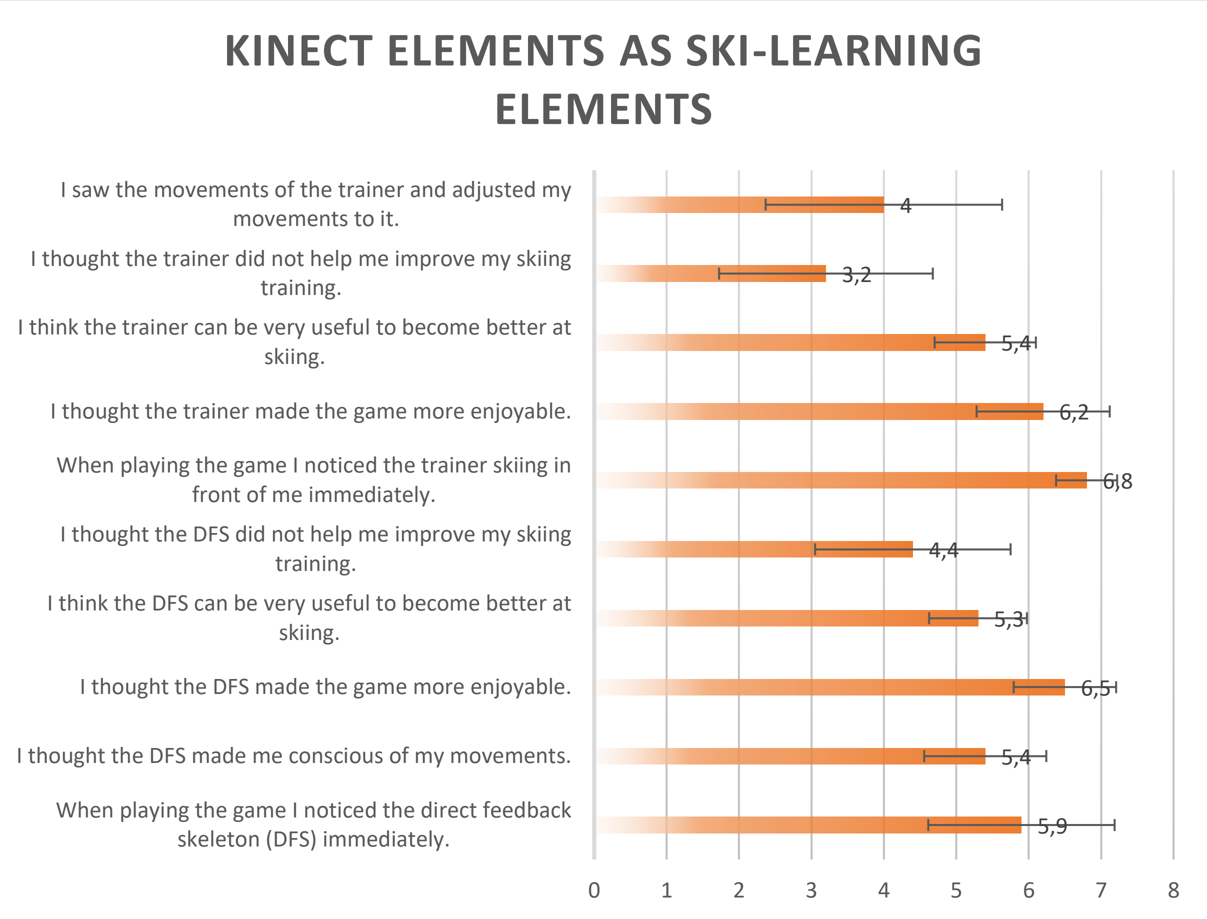


Figure 7.7. *Results of the Kinect elements as a ski-learning elements. Shown are the means and the standard deviations.*

Lastly, these statements concerned the Kinect elements (e.g. direct feedback skeleton (DFS) and the motion captured trainer) and the impact of their presence. It can be seen in **Figure 7.7** that all users immediately spotted the motion captured trainer (*mean: 6.8*) and almost everyone immediately spotted the direct feedback skeleton (*mean: 5.9*). The reason why this one is lower has two reasons: the resolution of the HoloLens screen is too small to fit the whole game plus the skeleton on it and that's why the users had to look a little bit more up to see it moving; the model takes a few seconds to appears, since the Kinect has to send the data over to the HoloLens.

From the graph it is also noticeable that both elements make the application more enjoyable (enjoyment of trainer *mean: 6.2*, enjoyment of direct feedback skeleton *mean: 6.5*). The subjects indicated that the motion captured trainer can be useful for becoming better at skiing, but that the movements of the trainer did not influence their behaviour. This was expected, because this test uses the movements of an experienced skier on the Pro Ski-Simulator, which gives no opportunities to perfect movements. *The average mean on the motion captured trainer is: 5.4*. The general opinion on the direct feedback skeleton was that it could be useful, but it needs some additions. Several subjects stated that it should have more functions: *"Receiving feedback of which movements are theoretically wrong and right for skiing."* and *"See whether the movements that the DFS shows as feedback are good or wrong movements."*. One subject indicated that the direct feedback skeleton was more of an distraction than an addition. It states: *"The Direct Feedback Skeleton was a bit of a distraction. I found myself trying to make it move in funny ways before I started doing the skiing exercise. Without the DFS, I might have been more focused on the task at hand."*. When the newer version of the direct feedback skeleton will be made it should contain the indicators of what movements the user should change or keep. This adds more functionality to it and might make it less of a distraction. *The average mean on the direct feedback skeleton is: 5.2.*

7.3.4 Other Remarks by Participants

"Sense of momentum forwards / sense of speed. It seemed like the mountain I was skiing down from was horizontal.". This remark has been added to the updated game.

"More advanced ski track (now it remains the same sequence of ski movements; that's predictable)". It is correct that the movement of the motion captured trained is predictable. However, this is done on the version of the Pro Ski-Simulator, because making movement adjustments on the machine is difficult and not desirable. The track the motion captured trainer currently follows is the most desirable path when using this machine.

"Maybe some atmospherically music.". Although this could be a feature worth trying most participants were amazed by the sounds heard when playing the application. The current sound makes the game feel more realistic and adds to the atmosphere.

"There were no points that could be obtained. This could make ik more enjoyable in my opinion.", *"System for points, or other gamification elements."* and *"Maybe a points system and another skin for the DFS"*. Initially it was a project requirement to add points to the game. However, because the requirement of tracking the users position was not finished in time and thus not fulfilled it was not possible to detect a collision between the player and a gate to add points. This could be added in the future when this requirement has been met.

8 CONCLUSION AND DISCUSSION

In this chapter the conclusion of the main research question is stated. Next, discussion points about the project are given and lastly ideas for future work are stated.

8.1 CONCLUSION

In the first chapter the main research question has been formulated.

RQ: "How to create an augmented reality skiing application for on a portable slope where different types of hardware work together to support the ski-learning process ?"

To answer this main research question, three related sub-questions have been formulated. The first sub-question is: "*What type of hardware can be used best to add new elements to an AR skiing game?"*. The second sub-question is: *"What types of new elements can be implemented into the AR skiing game to support the ski-learning process?"*. And the third sub-question is: *"How do players of the game perceive the different types of elements in the game?"*. First the conclusion of the three sub-questions are discussed and answered followed by the answer on the main research question.

Sub-question1: After a brainstorm session with the client and supervisor it was decided to use a depth sensor to open up various new elements to the augmented reality game. Another option that was discussed was using self-build distance sensors to calculate the players location, but this was not optimal since a depth sensor could perform this action too. With depth sensors in mind a specification comparison of 11 different types was discussed and it was concluded that the Microsoft Kinect v2 offers the best possibilities for adding new elements to the game, because it offers the possibilities to tracks the skeletons of the users, it has a great range, has a build-in microphone and is one of the cheapest depth sensors on the market. Furthermore, a comparison of different types of AR HMD's was discussed and it was concluded that the Meta 2 AR would be used, but due to the company not delivering this device in time the Microsoft HoloLens was used during this project. This device contains similar specifications to the Meta 2 AR, but has a smaller FoV, which was more desirable for a better game experience. Based on this literature research, this project used the Microsoft Kinect v2 and the Microsoft HoloLens.

Sub-question 2: Using brainstorm sessions, stakeholder identification and PACT scenarios several ideas were thought of. After weighing out all the ideas to each other it was decided that this project will included four different elements: UI Menu that can be controlled by voice commands, a motion captured trainer that skis in front of the user to make the user follow him, a direct feedback skeleton that displays the real time movements of the user and the tracking of the users location to not be independent of the

Microsoft HoloLens, as this hardware costs a lot of money. By tracking the user, points could also easily be implemented. These elements were concluded to be enjoyable and useful to the game. During the realization phase, however, only three of these elements could be implemented due to time restraints. Based on literature research and results obtained during the ideation- and specification phase the elements that were implemented in the final product are:

- Direct Feedback Skeleton;
- Motion Captured Trainer;
- UI Menu, controllable by voice commands.

Sub-question 3: The results of the experiment using the Pro Ski-Simulator showed that the subjects generally enjoyed playing the game and find it interesting. On the Interest/Joy topic of the IMI the subjects scored the application a 5.5 on a 7-point Likert scale.

On the topic regarding the impact of the application as a ski-learning tool the subjects scored the game a 5.1 on a 7-point Likert scale. Although the application was initially meant to be played on a revolving ski slope the subjects indicated that playing the game on the Pro-Ski Simulator can also train the user at getting better at skiing.

Regarding the Kinect elements as Ski-learning elements the subjects indicated that both the motion captured 3D trainer as well as the direct feedback skeleton had impact on the ski-learning process. The average mean on the motion captured trainer is a 5.4 on a 7-point Likert scale. The average mean on the direct feedback skeleton is a 5.2 on a 7-point Likert scale. However, some impact goals of elements were not met (mostly due to having to test on the Pro Ski-Simulator). A goal of the motion captured trainer was that users could mimic its movements to improve theirs.

Now the main research question can be answered. Creating an augmented reality application to support the ski-learning process by using an augmented reality HMD in combination with a depth sensor opens up many different types of elements. Feedback can be given to the player, because it’s movements are being tracked. These movements can be stored as data and send to the application on the AR HMD to create a 3D model that reads this data and uses it to mimic the movements of the player. This type of direct feedback does make the user more conscious of its movements, thus helping the ski-learning process. Because of the primal instincts of mimicking a 3D model containing movements of a advanced skier can help users become better skiers. These movements can be recorded by using the Kinect v2. So, using different types of hardware (i.e. Microsoft Hololens and Microsoft Kinect v2) can improve the ski-learning process while using, in this case, the Pro Ski Simulator. When on an actual revolving ski slope the impact should increase significantly, since this machine will recreate the ski atmosphere even more.

8.2 DISCUSSION

The goal of the project was to test the application on a revolving skiing slope. However, this was not possible during this project since I didn't have the option to use this device. Instead I used the Pro Ski-Simulator, which does not have the actual skiing movements but comes close as it is used as a ski warm-up device. Since the results of the experiments on the Pro Ski-simulator were strictly positive and it was concluded that the application in combination with the device does improve ski-learning the impact of the application on the revolving ski slope should be drastically higher. The movements recorded for the motion captured trainer were also performed on the Pro Ski-Simulator, thus making the movements less valuable to mimic. When the option arises to record an advanced/professional skier on the revolving ski track the impact of the primal instinct of mimicking should also drastically improve.

The results of the experiments could be slightly biased as the participants were mainly friends of mine. I did ask to fill in the survey as honest as possible to prevent a biased result. For further research more participants should be examined who are outside of my acquaintance-circle. This will reduce the biased results.

The looks of the direct feedback skeleton are currently the skin of a zombified person. Although this was not desired it was the only option as two weeks of trying to change it were unsuccessful. I decided to invest more time in the motion captured trainer to get this element as close to perfection as hoped. The skin of the direct feedback manager could influence the results of the test, because this could be more of a distraction. For further research this skin should be changed to a skeleton looking 3D model.

One of the goals of the project was not fulfilled, which was the goal to track the player's position using the depth sensor instead of the AR HMD. This could open up the option to use cheaper AT HMD's. The risk could be that there might be a visible delay, because obtaining the data from the Kinect, sending it to a server, the application on the HoloLens having to obtain the data and translating it into the correct position could take a visible amount of lag.

8.3 FUTURE WORK

To improve the impact and effectiveness of the application regarding the ski-learning process several updates should be implemented. First, the direct feedback skeleton currently makes the users conscious of their movements. Instead of making them aware of their movements actual hints could be given to the user by indicating their mistake. For example, the skeleton's leg could turn red and display a text message (or a voice) that indicates what the user should change in their movement in the future. This type of direct feedback should increase the users ski-learning abilities. This can be done by recording the movement of an advanced/professional skier while playing the game. The recorded skeleton shall be compared in real-time with the tracked skeleton of the user. When the movement differentiates too much with the movement of the recorded skier it could indicate what went wrong.

Second, instead of having the AR HMD (in this case the Microsoft HoloLens) track the position of the user to navigate through the course, the Microsoft Kinect v2 should track the position of the player and use this data to move the location of the user. This opens up the possibility of using a different, and possibly cheaper, type of AR HMD. When tracking the player using the depth sensor a point system can easily be introduced. By adding gamification elements the enjoyment of the application could improve to motivate players even more. This can easily be done by tracking both the data of the players location and comparing it to the location data of the gates. When these data are equal points could be given to the player. By adding rewards and leaderboards the extrinsic motivation of the users could be addressed to make the application more desirable to play.

Third, the transition from the Pro Ski-Simulator to the revolving ski slope should be implemented. The impact of the application should grow and the recorded movements of the motion captured trainer would be way more realistic. They would then actually perform the movements as intended and not the static and repeated movements recorded on the Pro Ski Simulator. This would make more random movements possible which could increase the enjoyability and functionality of the gane.

Lastly, different types of levels could be introduced to make the application less monotone. Each level could address a different type of skiing manoeuvre to give players the chance to train multiple aspects of the sport. Using the existing UI menu different scenes could easily be appointed to the correct button. The main framework for this already exist inside of the code.

9 REFERENCES

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Computer Graphics and Applications*, *21*(6), 34–47. https://doi.org/10.1109/38.963459

Benyon, D., & Macaulay, C. (2002). Scenarios and the HCI-SE design problem. *Interacting with Computers*, *14*(4), 397–405. https://doi.org/10.1016/S0953-5438(02)00007-3

Brière, N. M., Vallerand, R. J., Blais, M. R., & Pelletier, L. G. (1995). Développement et Validation d'une Mesure de Motivation Intrinsèque, Extrinsèque et d'Amotivation en Contexte Sportif: L'Échelle de Motivation dans les Sports (ÉMS) [Development and validation of a scale on intrinsic and extrinsic motivation and lack of mo. *International Journal of Sport Psychology*, *26*(4), 465–489.

Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., & Ivkovic, M. (2010). Augmented reality technologies, systems and applications. *Multimedia Tools and Applications*, *51*(1), 341–377. https://doi.org/10.1007/s11042-010-0660-6

Clancy, R. B., Herring, M. P., & Campbell, M. J. (2017). Motivation Measures in Sport: A Critical Review and Bibliometric Analysis. *Frontiers in Psychology*, *8*, 348. https://doi.org/10.3389/fpsyg.2017.00348

Clegg, D., & Barker, R. (1994). *Fast-track : a RAD approach*. Addison-Wesley Pub. Co. Retrieved from https://dl.acm.org/citation.cfm?id=561543

Cockburn, A. (2000). *Writing Effective Use Cases* (1st ed.). Pearson Education (Us).

Deci, E. L., & Ryan, R. M. (1985). The general causality orientations scale: Self-determination in personality. *Journal of Research in Personality*, *19*(2), 109–134. https://doi.org/10.1016/0092-6566(85)90023-6

Deci, E. L., & Vansteenkiste, M. (2004). Self-determination theory and basic need satisfaction: Understanding human development in positive psychology. *Ricerche Di Psichologia*, *27*, 17–34.

Dix, A., Finlay, J., Abowd, G. D., & Beale, R. (2004). *Human-Computer Interaction* (3rd ed.). Pearsin Prentice Hall. Retrieved from http://fit.mta.edu.vn/files/DanhSach/__Human_computer_interaction.pdf

Duda, J. L. (1989). Relationship between Task and Ego Orientation and the Perceived Purpose of Sport among High School Athletes. *Journal of Sport and Exercise Psychology*, *11*(3), 318–335. https://doi.org/10.1123/jsep.11.3.318

Eason, K. (1988). *Information Technology And Organisational Change*. Taylor & Francis. Retrieved from https://books.google.nl/books?hl=en&lr=&id=7BaH07ob6zQC&oi=fnd&pg=PP1&dq=Eason,+K.+(1987)+Information+Technology+and+Organisational+Change,&ots=qzJ7PHUwaR&sig=GHxP0fR9WODqW0um1IJChAUjlV8#v=onepage&q=Eason%252C%2520K.%2520(1987)%2520Information%2520Technol

Franscisco-Aparicio, A., Gutiérrez-Vela, F. L., Isla-Montes, J. L., & Sanchez, J. L. G. (2013). Gamification: analysis and application. *New Trends in Interaction, Virtual Reality and Modeling*, 113–123. Retrieved from https://link.springer.com/chapter/10.1007%2F978-1-4471-5445-7_9

Göbel, S., Hardy, S., Wendel, V., Mehm, F., & Steinmetz, R. (2010). Serious Games for Health: Personalized Exergames. In *Proceedings of the 18th ACM International Conference on Multimedia* (pp. 1663–1666). New York, NY, USA: ACM. https://doi.org/10.1145/1873951.1874316

González-Haro, C., Calleja-González, J., & Escanero, J. F. (2010). Learning styles favoured by professional, amateur, and recreational athletes in different sports. *Journal of Sports Sciences*, *28*(8), 859–866. https://doi.org/10.1080/02640411003734077

Grolnick, W. S., & Ryan, R. M. (1989). Parent styles associated with children's self-regulation and competence in school. *Journal of Educational Psychology*, *81*(2), 143–154. https://doi.org/10.1037/0022-0663.81.2.143

Guay, F., Vallerand, R. J., & Blanchard, C. (2000). On the Assessment of Situational Intrinsic and Extrinsic Motivation: The Situational Motivation Scale (SIMS). *Motivation and Emotion*, *24*(3), 175–213. https://doi.org/10.1023/A:1005614228250

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does Gamification Work? -- A Literature Review of Empirical Studies on Gamification. In *2014 47th Hawaii International Conference on System Sciences* (pp. 3025–3034). Retrieved from http://ieeexplore.ieee.org/xpls/icp.jsp?arnumber=6758978#keywords

Kolb, D. A. (1984). *Experiential learning: experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall. Retrieved from http://www.learningfromexperience.com/images/uploads/process

Kumar, J. (2013). Gamification at work: Designing engaging business software. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (pp. 528–537).

Linden, A., & Fenn, J. (2003). Gartner Strategic Analysis Report Understanding Gartner's Hype Cycles Understanding Gartner's Hype Cycles Understanding Gartner's Hype Cycles. Retrieved from http://www.bus.umich.edu/KresgePublic/Journals/Gartner/research/115200/115274/115274.pdf

Lonsdale, C., Hodge, K., Hargreaves, E. A., & Ng, J. Y. Y. (2014). Comparing sport motivation scales: A response to Pelletier et al. *Psychology of Sport and Exercise*, *15*(5), 446–452. https://doi.org/https://doi.org/10.1016/j.psychsport.2014.03.006

Lonsdale, C., Hodge, K., & Rose, E. A. (2008). The Behavioral Regulation in Sport Questionnaire (BRSQ): Instrument Development and Initial Validity Evidence. *Journal of Sport and Exercise Psychology*, *30*(3), 323–355. https://doi.org/10.1123/jsep.30.3.323

Lowy, A., & Hood, P. (2004). *The power of the 2x2 matrix : using 2x2 thinking to solve business problems and make better decisions* (1st ed.). Jossey-Bass. Retrieved from https://books.google.nl/books?hl=en&lr=&id=RvPNf89a7FYC&oi=fnd&pg=PA267&dq=learning+styles&ots=l_uA-DdOYW&sig=DCERQo222bwSXcqL6I48tJvUM_s#v=onepage&q=learning styles&f=true

Mader, A., & Eggink, W. (2014). A design process for creative technology. Retrieved from http://doc.utwente.nl/92543/

Mallett, C., Kawabata, M., Newcombe, P., Otero-Forero, A., & Jackson, S. (2007). *Sport Motivation Scale-6 (SMS-6): a revised six-factor sport motivation scale*. *Psychology of Sport and Exercise* (Vol. 8). https://doi.org/10.1016/j.psychsport.2006.12.005

Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. *Cognitive Science*, *5*(4), 333–369. Retrieved from https://www.scopus.com/record/display.uri?eid=2-s2.0-49049148395&origin=resultslist&sort=plf-f&src=s&st1=+Toward+a+Theory+of+Intrinsically+Motivating+Instruction&st2=&sid=E6B6F2494F80F35FE282C50C34D73A91.wsnAw8kcdt7IPYLO0V48gA%3A20&sot=b&sdt=b&sl=71&s=TIT

Malone, T. W. (1982). Heuristics for

Designing Enjoyable User Interfaces: Lessons from Computer Games. In *Proceedings of the 1982 Conference on Human Factors in Computing Systems* (pp. 63–68). New York, NY, USA: ACM. https://doi.org/10.1145/800049.801756

Martens, M. P., & Webber, S. N. (2002). Psychometric Properties of the Sport Motivation Scale: An Evaluation with College Varsity Athletes from the U.S. *Journal of Sport & Exercise Psychology*, *24*(3), 254–270. https://doi.org/10.1123/jsep.24.3.254

McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric Properties of the Intrinsic Motivation Inventory in a Competitive Sport Setting: A Confirmatory Factor Analysis. *Research Quarterly for Exercise and Sport*, *60*(1), 48–58. https://doi.org/10.1080/02701367.1989.10607413

McLeod, S. . (2013). Kolb - Learning Styles. Retrieved October 16, 2017, from https://www.simplypsychology.org/learning-kolb.html

Mekler, E. D., Brühlmann, F., Tuch, A. N., & Opwis, K. (2017). Towards understanding the effects of individual gamification elements on intrinsic motivation and performance. *Computers in Human Behavior*, *71*, 525–534. https://doi.org/10.1016/j.chb.2015.08.048

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1994). Augmented Reality: A class of displays on the reality-virtuality continuum, *2351*. Retrieved from http://wiki.commres.org/pds/Project_7eNrf2010/_5.pdf

Pelletier, L. G., Rocchi, M. A., Vallerand, R. J., Deci, E. L., & Ryan, R. M. (2013). Validation of the revised sport motivation scale (SMS-II). *Psychology of Sport and Exercise*, *14*(3), 329–341. https://doi.org/https://doi.org/10.1016/j.psychsport.2012.12.002

Pelletier, L. G., Tuson, K. M., Fortier, M. S., Vallerand, R. J., Briére, N. M., & Blais, M. R. (1995). Toward a New Measure of Intrinsic Motivation, Extrinsic Motivation, and Amotivation in Sports: The Sport Motivation Scale (SMS). *Journal of Sport and Exercise Psychology*, *17*(1), 35–53. https://doi.org/10.1123/jsep.17.1.35

Przybylski, A. K., Rigby, C. S., & Ryan, R. M. (2010). A Motivational Model of Video Game Engagement. *Review of General Psychology*, *14*(2). https://doi.org/10.1037/a0019440

Reeves, B., & Read, J. . (2009). *Total Engagement: Using Games and Virtual Worlds to Change the Way People Work and Businesses Compete*. Harvard Business Press.

Roberts, G. C., Treasure, D. C., & Balague, G. (1998). Achievement goals in sport: The development and validation of the Perception of Success Questionnaire. *Journal of Sports Sciences*, *16*(4), 337–347. https://doi.org/10.1080/02640419808559362

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology*, *25*(1), 54–67. https://doi.org/10.1006/ceps.1999.1020

Ryan, R. M., P. Connell, J., & Grolnick, W. S. (1992). *When achievement is not intrinsically motivated: A theory of internalization and self-regulation in school*. *Achievement and Motivation: A Social-Developmental Perspective* (Vol. 167).

Sharp, H., Finkelstein, A., & Galal, G. (1999). Stakeholder identification in the requirements engineering process. In *Proceedings. Tenth International Workshop on Database and Expert Systems Applications. DEXA 99* (pp. 387–391). IEEE. https://doi.org/10.1109/DEXA.1999.795198

Sutherland, I. E., & E., I. (1968). A head-mounted three dimensional display. In *Proceedings of the December 9-11, 1968, fall joint computer conference, part I on - AFIPS '68 (Fall, part I)* (p. 757). New York, New York, USA: ACM Press. https://doi.org/10.1145/1476589.1476686

Vallerand, R. J., & Blssonnette, R. (1992). Intrinsic, Extrinsic, and Amotivational Styles as Predictors of Behavior: A Prospective Study. *Journal of Personality*, *60*(3), 599–620. https://doi.org/10.1111/j.1467-6494.1992.tb00922.x

van Vliet, H. (2008). *Software engineering : principles and practice*. John Wiley & Sons. Retrieved from http://dl.acm.org/citation.cfm?id=1481475

Wasenmüller, O., & Stricker, D. (2017). Comparison of Kinect V1 and V2 Depth Images in Terms of Accuracy and Precision. In C.-S. Chen, J. Lu, & K.-K. Ma (Eds.), *Computer Vision -- ACCV 2016 Workshops: ACCV 2016 International Workshops, Taipei, Taiwan, November 20-24, 2016, Revised Selected Papers, Part II* (pp. 34–45). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-54427-4_3

10 APPENDIX

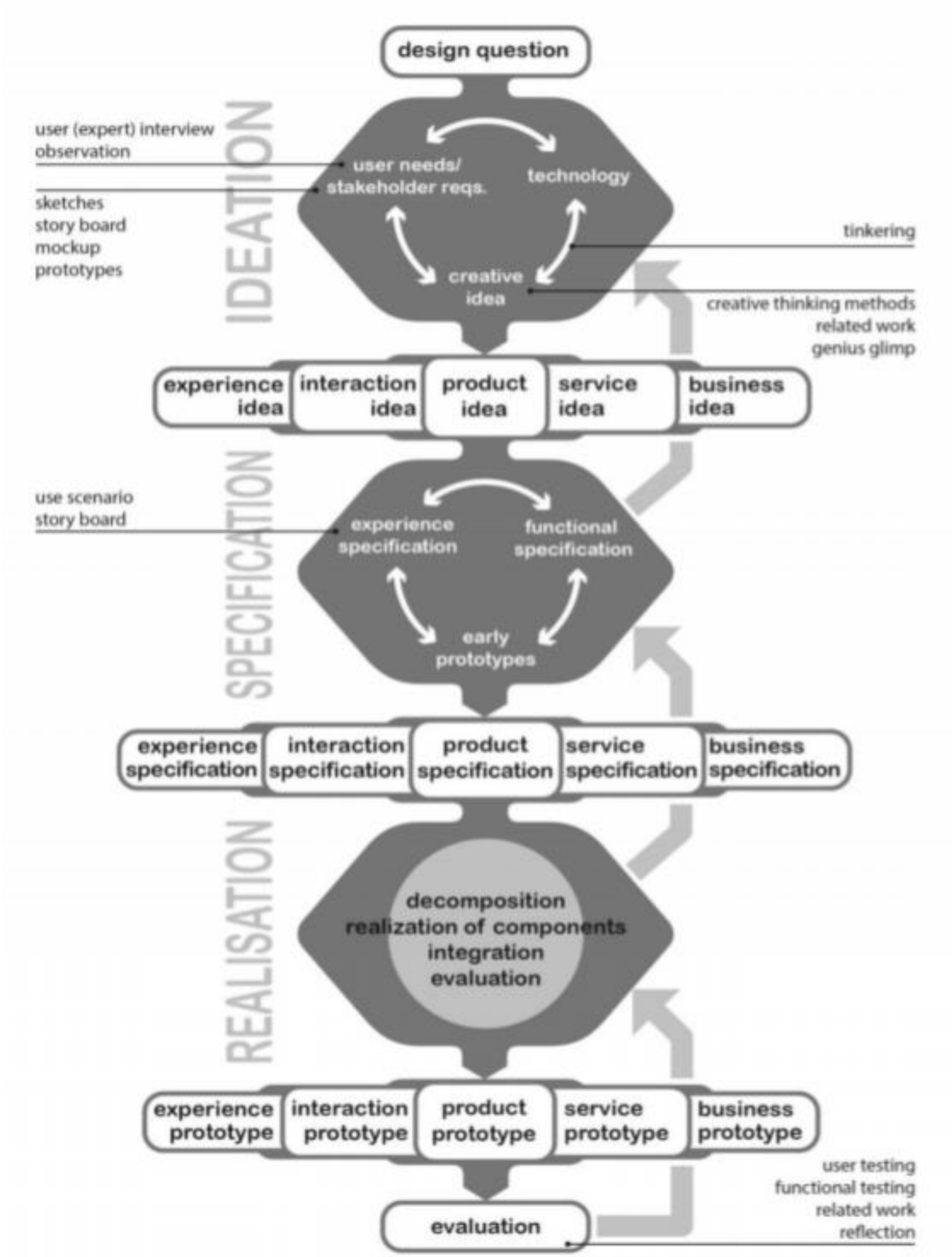
Appendix A: specification comparison Depth Sensors [14]

	Occipital Structure	Orbbec Persee	RealSense SR300	Orbbec Astra	RealSense R200	ZED Stereo Camera
Released	February 2014	December 2016	March 2016	September 2015	September 2015	May 2015
Price	$499 (bundle)	$240	$150	$150	$99	$449
Tracking Method	IR	IR	IR	IR	IR	Stereo RGB cameras
Range	0.4m – 3.5m	0.4m – 8m	<u>0.2m – 1.2m</u>	0.4m – 8m	<u>0.5m – 3.5m</u>	1.5m – 20m
RGB Image	iOS Camera resolution	1280×720, 30 FPS	1920×1080, 30 FPS	1280×960, 10 FPS	1920×1080, 30 FPS	configurable between 1280×480, 120 FPS and 4416×1242, 15 FPS
Depth Image	640×480 at 30fps, 320×240 at 60fps	640×480, 16 bit, 30 FPS	640×480, 60 FPS	640×480, 16 bit, 30 FPS	640×480, 60 FPS	configurable between 640×480, 120 FPS and 2208×1242, 15 FPS
Connectivity	Lightning on iOS, USB elsewhere	Ethernet	USB 3.0	USB 2.0	USB 3.0	USB 3.0
Physical Dimensions	119.2×28×29 mm	172×63×56 mm	14×20×4 mm	160×30×40 mm	130×20×7 mm	175×30×33 mm
Works outdoors?	✗	✗	✗	✗	✗	✓
Skeleton tracking?	✗	✗	✗	✓ (only hand positions)	✗	✗
Facial tracking?	✗	soon	✓	✗	✓	✗
3D scanning?	✓	✗	✓	✗	✓	✓
Simultaneous apps?	✗	soon	✓	✗	✓	✗
Gesture Training?	✗	✗	✗	✗	✗	✗
Gesture Detection?	✓	✗	✓	✗	✗	✗
Toolkits	iOS, Unity3D, OpenNI	C++, Java, OpenNI, ROS	Java, JavaScript, Processing, Unity3D, Cinder	OpenNI	Java, JavaScript, Processing, Unity3D, Cinder	
Project Examples	Lots of examples on 3D scanning, mixed reality and indoor navigation	Depth Data Viewer, RGB Data Viewer	Various face tracking examples, mostly with C++. Only one Unity3D sample.	HandViewer, Depth Data Viewer, RGB Data Viewer	Various face tracking examples, mostly with C++. Only one Unity3D sample.	Background subtraction, right image disparity, depth map

[14] Source: https://stimulant.com/depth-sensor-shootout-2/

	RealSense F200	Kinect for XBox One	Duo mini lx	Leap Motion	Kinect for XBox 360
Released	January 2015	July 2014	May 2013	October 2012	June 2011
Price	$99	$100	$695	$100	Unavailable
Tracking Method	IR	IR	Passive IR	IR	IR
Range	0.2m – 1.2m	0.5m – 4.5m	0.3m – 2.4m	0.025m – 0.6m	0.4m – 4.5m
RGB Image	1920×1080, 30 FPS	1920×1080, 30 FPS	configurable between 320×120, 360 FPS and 752×480, 56 FPS	N/A	640×480, 30 FPS
Depth Image	640×480, 60 FPS	512×424, 30 FPS	configurable between 320×120, 360 FPS and 752×480, 56 FPS	20 to 200+ FPS	320×240, 30 FPS
Connectivity	USB 3.0	USB 3.0	USB 2.0	USB 2.0	USB 2.0
Physical Dimensions	150×30×58 mm	250×66×67 mm	52×25×11 mm	76×30×17 mm	280×64×38 mm
Works outdoors?	✗	✗	✓	✗	✗
Skeleton tracking?	✗	✓ (six skeletons)	✗	✗	✓ (two skeletons)
Facial tracking?	✓	✓	✓	✗	✓
3D scanning?	✓	✓	✓	✗	✓
Simultaneous apps?	✓	✓	✗	✗	✗
Gesture Training?	✗	✓ (Visual Gesture Builder)	✗	✓	✗ (only via third-party tools)
Gesture Detection?	✓	✓ (hand open, closed, lasso)	✗	✓	✓ (hand grip, release, press, scroll)
Toolkits	Java, JavaScript, Processing, Unity3D, Cinder	WPF, Cinder, OpenFrameworks, JavaScript, vvvv, Processing, Unity3D, more	Dense3D, OpenCV, Qt5	Javascript, Oculus Rift, Unity3D, Unreal	WPF, Cinder, OpenFrameworks, JavaScript, vvvv, Processing, Unity3D, more
Project Examples	Many examples of face tracking, gesture tracking, speech detection on a variety of different platforms and frameworks	Many examples of skeleton tracking, face tracking, and speech detection on a variety of different platforms and frameworks	Very few samples in each of the supported languages, mostly to get raw image and depth data	There are a number of examples available for each of the lanugaes and platforms supported	Many examples of skeleton tracking, face tracking, and speech detection on a variety of different platforms and frameworks

Appendix B: Creative Technology Design Process



(Mader & Eggink, 2014)

Appendix C: SMS-II Questionnaire

Why do you play your sport?

Circle the most accurate answer on the 7 point scale for each statement.

1) Because people around me reward me when I do.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

2) Because it gives me pleasure to learn more about my sport.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

3) Because I would feel bad about myself if I did not take the time to do it.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

4) Because practicing sports reflects the essence of whom I am.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

5) Because through sport, I am living in line with my deepest principles.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

6) Because I think others would disapprove of me if I did not.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

7) Because it is very interesting to learn how I can improve.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

8) So that others will praise me for what I do.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

9) Because I have chosen this sport as a way to develop myself.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

10) It is not clear to me anymore; I don't really think my place is in sport.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

11) Because it is one of the best ways I have chosen to develop other aspects of myself.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

12) Because I feel better about myself when I do.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

13) Because I find it enjoyable to discover new performance strategies.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

14) Because I would not feel worthwhile if I did not.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

15) Because participating in sport is an integral part of my life.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

16) Because people I care about would be upset with me if I didn't.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

17) Because I found it is a good way to develop aspects of myself that I value.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

18) I used to have good reasons for doing sports, but now I am asking myself if I should continue.
1 2 3 4 5 6 7
(Not at all true) (somewhat true) (Very true).

Scoring Key

(scorers see Scoring Key for how to Score the SMS II)

SCORING KEY for SMS II and the RAI

Scoring of SMS II: (Add (sum) category scores below to get the RAI)

Intrinsic [(Total score of 3 items) * (3)]= Intrinsic Score= __________
#2. Because it gives me pleasure to learn more about my sport.
#13. Because I find it enjoyable to discover new performance strategies.
#7. Because it is very interesting to learn how I can improve.

Integrated [(Total score of 3 items) * (2)]= Integrated Score= __________
#4. Because practicing sports reflects the essence of whom I am.
#15. Because participating in sport is an integral part of my life.
#5. Because through sport, I am living in line with my deepest principles.

Identified [(Total score of 3 items) * (1)]= Identified Score= __________
#9. Because I have chosen this sport as a way to develop myself.
#17. Because I found it is a good way to develop aspects of myself that I value.
#11. Because it is one of the best ways I have chosen to develop other aspects of myself.

Introjected (Reverse Score) [(Total score of 3 items) * (-1)]= Introjected Score= _______
#3. Because I would feel bad about myself if I did not take the time to do it.
#12. Because I feel better about myself when I do.
#14. Because I would not feel worthwhile if I did not.

External (Reverse Score) [(Total score of 3 items) * (-2)]= External Score= __________
#16. Because people I care about would be upset with me if I didn't.
#6. Because I think others would disapprove of me if I did not.
#1. Because people around me reward me when I do.

Amotivated (Reverse Score) [(Total score of 3 items) * (-3)]= Amotivated Score=

____

#18. I used to have good reasons for doing sports, but now I am asking myself if I should continue.
#8. So that others will praise me for what I do.
#10. It is not clear to me anymore; I don't really think my place is in sport.

The Relative Autonomy Index (RAI)- The relative autonomy index (RAI) is a single score derived from the

subscales that gives an index of the degree to which respondents feel self-determined. The index is obtained by applying a weighting to each subscale and then summing these weighted scores. In other words, each subscale score is multiplied by its weighting and then these weighted scores are summed.

RAI=

Intrinsic_+ Integrated_+ Identified_+ Introjected_+External_+ Amotivated

Example:

= Intrinsic (15*3)+ Integrated (18*2)+ Ident (16*1)+ Introjected (12*-1)+ Ext(12*-2)+ Amotive(6*-3)

= Intrinsic (45) + Integrated (36)+ Ident (16)+ Introjected (-12)+ External(-24)+Amotive(-18)

= 45 + 36 + 16 + (-12) + (-24) + (-18).

= 97 + (-54)

= 43

RAI = 43. Relative Autonomy Index Score is 43.

Appendix D: Heuristics for Designing Enjoyable User Interfaces

I. Challenge

A. *Goal*. Is there a clear goal in the activity? Does the interface provide *performance feedback* about how close the user is to achieving the goal?

B. *Uncertain outcome*. Is the outcome of reaching the goal uncertain?

1. Does the activity have a variable difficulty level?. For example, does the interface have successive layers of complexity?

2. Does the activity have multiple level goals? For example, does the interface include scorekeeping?

II. Fantasy

A. Does the interface embody *emotionally appealing* fantasies?

B. Does the interface embody *metaphors* with physical or other systems that the user already understands?

III. Curiosity

A. Does the activity provide an optimal level of *informational complexity*?

1. Does the interface use *audio and visual effects*: (a) as decoration, (b) to enhance fantasy, and (c) as a representation system?

2, Does the interface use *randomness* in a way that adds variety without making tools unreliable?

3. Does the interface use *humour* appropriately?

B. Does the interface capitalize on the users' desire to have "*well-formed*" *knowledge structures*? Does it introduce new information when users see that their existing knowledge is: (1) *incomplete*, (2) *inconsistent*, or (2) *unparsimonious*?

(Malone, 1982)

Appendix E: Modified IMI-questionnaire

All statements can be graded with a grade from 1 to 7. 1 begin "not true at all" and 7 being "very true".

Section 1: Interest and Joy evaluation

I enjoyed playing this game

This game was fun to do

I thought this game was boring

This activity did not hold my attention at all

I would describe this game as very interesting

I thought this game was quite enjoyable

While I was playing this game, I was thinking about how much I enjoyed it

Section 2: The application as a ski-learning application

I believe this game could be of some value to me as skiing practice

I think that playing the game is useful for getting better at skiing

I think this is important to do because it can help me to get better at skiing

I would be willing to do this again because it has some value to me

I think doing this activity could help me become a better skier

I believe doing this activity could be beneficial to me

I think this is an important activity to become a better skier

Section 3: Kinect elements as ski-learning elements

When playing the game I noticed the direct feedback skeleton (DFS) immediately

I thought the DFS made me conscious of my movements

I thought the DFS made the game more enjoyable

I think the DFS can be very useful to become better at skiing

I thought the DFS did not help me improve my skiing training

When playing the game I noticed the trainer skiing in front of me immediately

I thought the trainer made the game more enjoyable

I think the trainer can be very useful to become better at skiing

I thought the trainer did not help me improve my skiing training

I saw the movements of the trainer and adjusted my movements to it

Section 4: General questions for better understanding

The actions I performed in the physical world had influence on the game

There was no correlation between my actions in the physical world and the game

I would like to play this game again

I think playing this game more regularly would help me improve my skiing skills

Appendix F: Outlines Semi-structured Interview

Semi-Structured Interview

Vragen over de game in het algemeen.

Je hebt nu net de game gespeeld.

- Wat is je eerste indruk van het spel?
- Vond je het moeilijk om het spel te begrijpen? … Waarom?
- Vond je dat het menu een handige functie van het spel was? … Waarom?
- Vond je de omgeving een toevoeging hebben aan een echte ski sfeer? … Waarom?
  - Geluid
  - Omgevings objecten
- Wat miste je nog tijdens het spelen van het spel?
- Wat zou je nog toevoegen aan het spel?

Vragen over de toegevoegde Kinect elementen.

Door de kinect toe te voegen aan de game zijn er nieuwe mogelijkheden geopend die de game kunnen versterken. In dit spel heb ik twee elementen toegevoegd: de Direct Feedback Skeleton en de Motion Captured Trainer.

- Wat vond je van deze elementen in het spel?
  - Direct Feedback Skeleton
  - Motion Captured Trainer
- Vond je de elementen een positieve toevoeging aan het spel? … Waarom?
- Wat zou je toevoegen of weglaten aan deze elementen?

Vragen over de toegevoegde waarde van de game.

- Denk je dat dit spel een ski training leuker maakt? … Waarom?
- Denk je dat dit spel mensen kan helpen beter te worden in skiën? … Waarom?
- Zou je het spel vaker spelen? … Waarom?
- Denk je dat als je dit spel regelmatig speelt dat het je ski skills in het algemeen zal verbeteren? … Waarom?

- Heb je nog opmerkingen in het algemeen?

Appendix E: Playtesting menu results

Go to Settings and turn off the sound. 4 responses

It was very easy to find the Settings button. I saw the flashing text at the bottom and guessed I had to say the name of the button. It was also very easy to turn off the sound. The indication with the dot next to the button was helpful.

Clear what to say ("Settings" - "Off")

Easy to find settings menu and no problem turning the sounds off.

Was easy to navigate through the menu to turn off the sound

From the Settings Menu, go to and select the 'Slalom Training' game mode. 4 responses

It was easy to use the back button. Start seemed like the only option to get to the game. It was clear what to say.

Clear what to say ("Back - "Slalom Training")

Using the back button followed by start I could select the Slalom Training.

Also easy to find my way back to the main menu and select the right game mode.

Play the game for a while, then Pause the game and Restart the level. 4 responses

I didn't know how to Pause and Restart the game. After asking I needed to say Help to access the other commands. Maybe show the commands in the first fice seconds after which they can dissappear? Pause and Restart worked after knowing

No idea what to say (except for restart). To pause it was "Stop". This has to be better

Had no idea how to pause. Restart was a guess, but worked.

Did not know how to pause the game. Restart worked but was a guess

From the 'Slalom Training' game mode, go back to the Main Menu and close the application. 4 responses

Saying Back worked immediately and then saying Quit worked good too. It was clear what to say (after having to ask for the Back command)

Clear what to say ("Back" - "Quit")

Using the back command and then the quit command I could perform the tasks easily

I guessed reading this I had to say back and it worked. Maybe add a help function?

Appendix F: HoloLens with unity5 tutorial

HoloLens setup with Unity5

Jop Paulissen 02-12-2017

Step 1: Installing the SDK + preparation.

- **Enable Virtualization**

When using the HoloLens emulator (for when an actual HoloLens is not available) you need to setup some settings to run virtual machines on your computer. To enable Virtualization go to your BIOS settings and look for Virtualization (VTx) and Enable it.

- **Enable Hyper-V**

For this you need Windows Pro, or the recommended Windows Educational (this one is free to download). Open Control Panel, and search “Turn Windows Features On or Off”. In here you can see the Hyper-V file. Click on the check box in front of it to enable it. Now, restart your computer as prompted.

- **Install Microsoft Visual Studio**

The latest version should work (I have Visual Studio 2017 Version 15.4.4). Download Visual Studio Community. Download link: https://www.visualstudio.com/downloads/

- **Install the HoloLens Emulator**

This emulator is perfect for when you don’t have a HoloLens available. Download link:
http://go.microsoft.com/fwlink/?LinkID=724053
If you do not have Virtualization enabled, you’ll get an error. If your computer does not support the emulator, you’ll get an error, too. After the Emulator is installed, restart your computer.

- **Install Unity**

Finally, you’ll have to install a Hololens-compatible version of Unity. Unity is a powerful gaming engine that helps you build 3D apps easily. Install the 64-bit or 32-bit Unity Editor.
Recommended version: Unity 2017.1.0p5. Download link: Download

Important: when installing Unity, make sure that you enable "Universal Windows Platform .net scripting backend".

- **Download the HoloLens SDK**

Download the latest release of the SDK here: https://github.com/Microsoft/MixedRealityToolkit-Unity/releases/

Step 2: Setting up the Unity Project

- Create new Unity project

Open up unity and create a new project. Make sure to **select 3D**, then press **Create project**.

- Load in the HoloLens SDK

In Unity press **‘Assets’** at the top. Then **‘Import Package’** followed by **‘Custom Package…’**. Now select **‘HoloToolkit-Unity-v1.2017.1.0.unitypackage’**. In the screen that pops up press **Import**. Now sit back and wait till everything is done loading, since this may take a while.

- Setting up the Camera and the correct settings

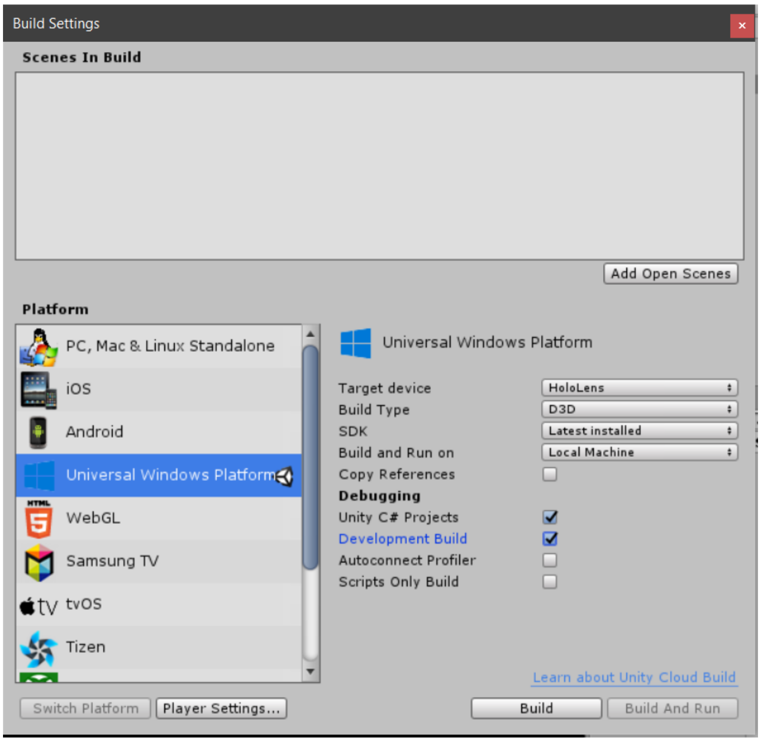
First delete the **Main Camera** in the Hierarchy. In the Project Window type in the search bar **“HoloLensCamera”** and drag this one into the Hierarchy. Then, at top of the screen the **HolotoolKi**t menu has appeared. Press here, then **“Configure”** followed by **“Apply HoloLens Project Settings”**. This applies the correct settings in Unity to build a HoloLens Application. A window will pop-up that will let you save the Scene. Name your scene and press **“Save”**. Unity will now restart.

Step 3: Add some 3D elements and Building the scene

- **Add a cube**

Now, let’s add our first 3D objects to our scene. Under the Hierarchy panel, select **Create → 3D Object → Cube.** This will add a cube to the scene. Use the **Position**, **Rotation**, and **Scale** properties to play with the cube. The Z value of the Position property indicates how far the object will be placed. Select a positive number to place the object in front of you. For example, if you set the Z value to “2”, the cube will be positioned 2 meters in front of you.

- **Platform Settings**



You can add more elements into your scene and create your own virtual 3D world. When you are finished, you'll need to deploy your app and test it using the Emulator. Unity supports a variety of deployment targets. However, Hololens is only compatible with the **Universal Windows Platform** deployment platform. Windows Store is the newest set of Microsoft APIs. To deploy for Windows Store, click **File → Build Settings**. The following popup window appears.

Press '**Add Open Scenes'** to load in the saved scene. Then press the Universal Windows Platform and press **'Switch Platform'**. Then in the image above you can see the settings that have to bee selected.

Target Device: HoloLens
Build Type: D3D
SDK: Latest Installed
Build and Run on: Local Machine

Make sure to select **Unity C# Projects** and **Development Build**.

- **Player Settings**

After specifying the build platform, you need to select the Universal Windows Platform capabilities of your app. Click **Player Settings**. The Inspector panel will show you some options. Select the blue Windows logo and find the Capabilities list. This can be found under '**Publishing Settings'** and scrolling down. The following elements should be checked, no matter what:

- *SpatialPerception*
- *Microphone*
- *InternetClient*

SpatialPerception indicates that your app will be capable of using the spatial mapping features. **Microphone** indicates that your app will be capable of using voice (Cortana) as an input. **InternetClient** indicates that your app will need network connectivity. Since the emulator is running as a Virtual Machine, you need to check this option, even if your app is not making any use of the Internet. If you do not check this option, you'll see an error after you deploy your app!

Under the Other Settings list, check the **Virtual Reality Supported** box. This will let your app run immersively in the 3D space. If left unchecked, the app will run as an ordinary 2D window.

- **Build**

Now press **Build** in the pop-up screen. Unity will ask you to specify a folder for your build. Create a new empty folder anywhere on your computer and click Select Folder. This will generate a Visual Studio solution file.

Step 4: Running the scene

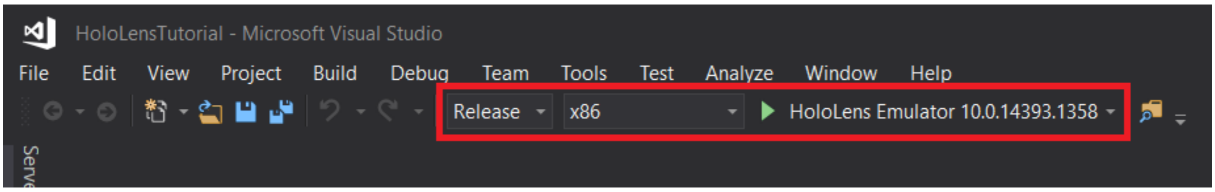
- **Launch Visual Studio Solution**

It may take a few minutes for Unity to create the Visual Studio solution. After the process is done, open the folder you created and **double-click the .sln file** to launch Visual Studio.

- **Run on HoloLens Emulator**

Visual Studio has packed the binaries and created a project bundle you can later submit to the Windows Store. To run your app, you need to modify the following parameters from the primary command bar:

  - Select Release as your target.
  - Select x86 as your architecture.
  - Select Hololens Emulator as your device.



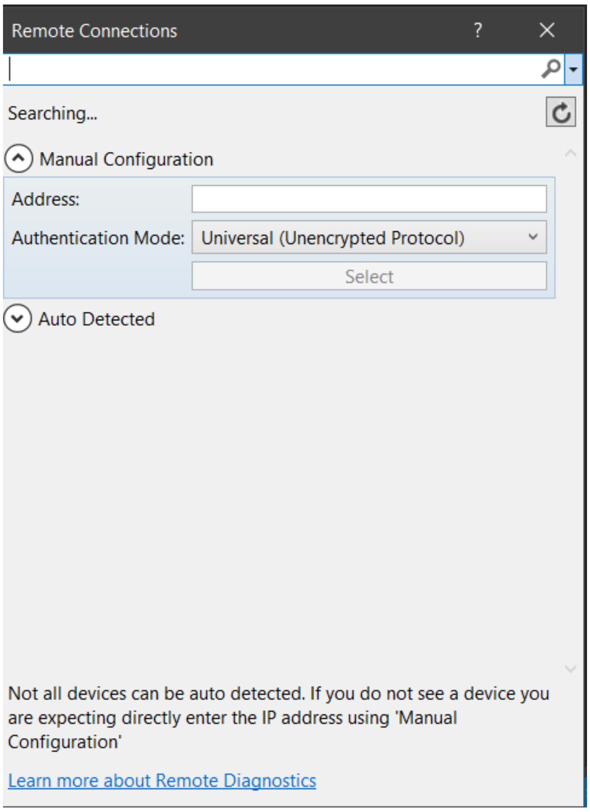
Then press the play button to Deploy. Hololens Emulator should launch after a while (it may take up to 15 minutes, though, so please be patient). After the Emulator is launched, you'll be able to see your cube and interact with it. Try rotating your view using the mouse and arrow keys. Hit the Enter or Space button to select something. The Emulator is like your field-of-view. The tiny circle is where you point.

Important: For the Emulator to run you need at least a minimum om 2048MB RAM available.

- **Run on HoloLens**

To run your app, you need to modify the following parameters from the primary command bar:

  - Select Release as your target.
  - Select x86 as your architecture.
  - Select Remote Machine as your device.



Important: Make sure you HoloLens is connected to the internet.

On the HoloLens open up the **Hologrpahic Remoting App**. An IP Adress will be shown. Enter the IP-Adress in the Pop-up in Visual Studio and press **Select**. When it's the first time you're pairing the HoloLens to Visual Studio it wil lask for a **Pin**. This can be found on the HoloLens. Go to Settings and press **Update & Security**. Then press **For Developpers** and press **Pair**. The pin shall be displayed. Type this pin into the Visual Studio pop-up screen to pair it.

Now press the play button at **Remote Machine**.

It will deploy the application on the HoloLens. Now in your HoloLens go the list of Applications and find your Unity Program. Open it and you'll see your beautifull creation through the hololens.