Interactive 360-degree videos with head-mounted displays in training paramedics

Master Thesis

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Declaration

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Bad Hofgastein, 14.05.2019

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Place, Date

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Signature

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Abstract

The Austrian population is increasing and gets older. With the increasing age, also the multi-morbidity and the need for care rises. This is also to be expected with an increase of older emergency patients and thus increases the frequency of cases in ambulance service. Not only the higher number of patients poses a great challenge to the rescue organizations. Also, the increased demands on the diagnostic and therapeutic competences of the rescue personnel, the doctor shortage and the fluctuation among the volunteers are issues.

Because of these aspects, the competence among the paramedics must be ensured. To a large extent this can be achieved through good education, training and assessment environments. Such good learning environments are distinguished by time-independency, repeatability, realistic and practical orientation. All these aspects can be addressed by 360-degree videos. Therefore, in this master thesis an interactive 360-degree trainings video in combination with a head-mounted display was developed. The duration of the 360-degree video is 8.48 minutes. Afterwards, it was evaluated with a questionnaire by ten paramedics. Content of the video was a case study with interactions. As interactions the participants have to answer five questions with three possible answers.

The developed 360-degree video was evaluated positive. All participants had fun to watch this 360-degree video and believe that such videos are a good possibility to support traditional training. 80 % felt that 360-degree videos convey content better than traditional education videos and 80 % could imagine using such 360-degree videos more often in combination with head-mounted displays. One participant got sick during watching and one participant suffers partially nausea. Almost all participants (90 %) felt as they were really in the situation, which means that the sense of presence was given. 40 % of the participants felt that wearing the head-mounted display was partly uncomfortable. 80 % of the participants agreed that the use of hotspots increases learning success. The individual selectable image section was also positively evaluated in this pilot study (80 %).

Based on the results of this pilot study, the hypothesis “360-degree videos are a good opportunity to improve or extend the knowledge of paramedics” can be generated.

Kurzfassung

Die österreichische Bevölkerung steigt und wird älter. Mit erhöhtem Alter steigen auch die Multimorbidität und der Pflegebedarf. Dadurch wird sich auch die Anzahl der älteren Patienten und Patientinnen im Rettungsdienst erhöhen. Abgesehen von der steigenden Anzahl an Patienten und Patientinnen führen auch die diagnostischen und therapeutischen Anforderungen an das Rettungspersonal zu einer Herausforderung. Weiters müssen der Ärztemangel und die Fluktuation bei den freiwilligen Mitarbeitern und Mitarbeiterinnen kompensiert werden.

Aufgrund dieser Aspekte muss die Kompetenz des Rettungspersonals sichergestellt werden. Größtenteils kann dies durch eine gute Aus- und Weiterbildung erreicht werden. Gute Lernumgebungen zeichnen sich durch Zeitunabhängigkeit, Wiederholbarkeit, Realitätsnähe und Praxisnähe aus. Diese Aspekte können mit einem 360-Grad-Video erreicht werden. Aus diesem Grund wurde in dieser Masterarbeit ein interaktives 360-Grad Trainingsvideo, mit Verwendung einer Virtual Reality-Brille, entwickelt. Die Gesamtdauer des 360-Grad Videos beträgt 8,48 Minuten. Im Anschluss wurde das Video von zehn Rettungssanitätern und Rettungssanitäterinnen anhand eines Fragebogens evaluiert. Inhalt des Videos ist ein Fallbeispiel mit Interaktionen. Die Interaktionen setzen sich aus fünf Fragen mit jeweils drei Antwortmöglichkeiten zusammen.

Das 360-Grad Video wurde positiv evaluiert. Alle Teilnehmer und Teilnehmerinnen hatten Spaß beim Betrachten des Videos und glauben, dass solche Videos eine gute Möglichkeit sind, um konventionelle Schulungen zu unterstützen. 80 % finden, dass 360-Grad Videos den Inhalt besser vermitteln können als herkömmliche Videos und könnten sich vorstellen, 360-Grad Videos in Kombination mit einer Virtual Reality-Brille öfters zu verwenden. Einem Teilnehmer oder einer Teilnehmerin wurde beim Betrachten des Videos schlecht und einem Teilnehmer oder einer Teilnehmerin wurde teilweise schlecht. 90 % der Teilnehmer und Teilnehmerinnen fühlten als wären sie wirklich in der Situation. Das bedeutet, dass das Gefühl von Präsenz gegeben war. 40 % der Teilnehmer und Teilnehmerinnen empfanden das Tragen der Virtual-Reality-Brille als unangenehm. 80 % stimmten zu, dass die Verwendung von Hotspots den Lernerfolg erhöht und beurteilten den selbstauswählbaren Bildausschnitt als positiv.

Basierend auf den Ergebnissen dieser Pilotstudie, wurde die Hypothese „360-Grad-Videos sind eine gute Möglichkeit, das Wissen von Sanitätern zu verbessern oder zu erweitern" aufgestellt.

Table of Content

1 Introduction

According to Statistic Austria [1] the Austrian population is increasing and gets older. The number of people over an age of 65 will increase by 50 % in the next 20 years. A prospective result is that more than 25 % of the population are over 65-year olds. Currently, only one fifth of the population is over 65 years of age. With the increasing age, also the multi-morbidity and the need for care rises. Therefore a doubling of older emergency patients can be expected and thus increases the frequency use of the ambulance service [2, p. 22].

1.1 Problem

Not only the increased number of patients poses a great challenge to the rescue organizations, but also the demands on the diagnostic and therapeutic competences of the rescue personnel, which are also due to the preclinical care [3]. In addition, in recent years, larger technical and medical-technical possibilities have been developed in the emergency service. Some examples are: telemedicine, non-invasive ventilation, 12-lead ECG [3]. Also the doctor shortage, the unclear development of the on-call service of the doctors and respectively the availability of the doctors for the increased patient population will be challenging for the ambulance services [2, p. 14], [4].

A further difficulty is that a large part of the prehospital emergency service is provided by volunteers. For volunteers, it is increasingly difficult to devote avocational to the emergency medical service. This leads to a high fluctuation among the employees. Especially the loss of experienced and/or service tested employees is very painful and hardly compensable. The frequent change of staff negatively affects the practical experience and leads to uncertainties in dealing with the patients. Maintaining appropriate skills is difficult due to the small number of cases. For compulsory internships, only the time and not the number of tasks, competences or clinical pictures are given. As a result, the emergency medical resources (for example doctors) were more required, and the quality of care is reduced [2, p. 164].

In terms of patient safety, these challenges result in increased demands on education, training and further education [3]. This leads to the following research questions.

1.2 Research Questions

1. How do interactive 360-degree videos affect the learning success?
2. Based on the results of the pilot study, is there any indication that the new way of training improves paramedic skills?
3. What are the advantages or disadvantages of training with interactive 360-degree videos?

1.3 Structure and Method

Chapter 2 gives an overview about the different topics which were combined in this thesis. First the Austrian Emergency Medical service is explained. Then virtual and augmented reality and their components will be discussed. For better understanding the effect of virtual reality and the human perception aspects were explained. For developing learning environments, it is important to know how the human memory and learning works. Therefore, these things were described in chapter 2.4. For the chapters containing the theoretical background mainly literature in the form of specialist books was used.

The chapter VR in education should give an overview of the possibilities of VR referenced to recent studies and should give informations to improve the developed 360-degree video .

Afterwards, the production and programming of the 360-degree training video is explained.

In chapter 4 the pilot study is described in more detail and contains information about the participants and the procedure. Following this, the results of the evaluation were presented.

The work is completed with a discussion on the test results and is based on the requirements, which were found during this study. The master thesis ends with the conclusion.

1.4 Goals

Through clear evidence-based and structured recommendations for diagnosis and treatment and if an action framework is defined in emergency situations, the quality of care will rise. This is achieved through practice-oriented and practically clear teaching concepts, which pursue contemporary methodological-didactic principles. In this regard, special attention should be paid to interactivity and the limitation of the number of participants. This will provide the participants with appropriate support and encouragement [2, pp. 176–177].

The aim of this thesis is to get an indication if 360-degree videos with interactions are a good opportunity to improve or extend the knowledge of paramedics and so increase the quality of care. At the end of this thesis a hypothesis should be generated.

2 Theoretical Background

In this chapter the emergency medical service in Austria and the education of paramedics are explained. Then virtual reality and augmented reality and the required components are described. To understand how virtual reality can be used, the perception aspects of virtual reality are explained. Then chapters follow, which deal with memory, learning and education with virtual reality.

2.1 Emergency Medical Service in Austria

According to Hellmilch [5, pp. 6–7] at the end of the 19th century, the first organized rescue services was created. The ambulance transports were carried out by so-called "orderly". In the past, aim of the emergency medical service was to arrive the patient quick and bring the patient as fast as possible in the hospital. But the aim of the medical rescue in the highly developed industrial countries has changed. In addition to reach the emergency patient quickly and the prevention of further damage, the priority is nowadays placed on the care of the patients. The goal is to restore, maintain or stabilize vital functions and then bring them to a hospital as soon as possible. This results in the four main requirements of the rescue service: easy accessibility, rapid arrival, appropriate medical care and careful transport. A properly trained staff and the right equipment plays a major role. From the former “orderly” the profession paramedic was generated. Today the level of education and the associated competences of the paramedics are also very different [5, pp. 6–7]. The training standards of the rescue service in Austria will be described in more detail in the next chapter.

In Austria, the communities or cities are responsible for the emergency medical service. But the legislation is land-based [5, p. 6]. In most cases approved rescue organisations (for example: *Österreichisches Rotes Kreuz*, *Arbeiter-Samariter-Bund*) were assigned to do the job, only in some cases for example in Vienna, the emergency medical service is a public owned organisation. Mostly all private organisations were responsible for transporting sick persons as well as for rescue service. Therefore, there is no or only an incomplete separation of these areas [2, p. 132].

The rescue service staff consists of full-time paramedics, civil servants and volunteers. The volunteers work mainly on weekend or in the night shift [2, p. 133].

2.1.1 Education of paramedics in Austria

Due to the paramedic law with legal framework, which was introduced in 2002, the training requirements have been precisely defined and must be implemented. The education of the rescue service personnel is divided into the two levels paramedic and emergency paramedic (Table 1). Both levels consist of a theoretical and practical education [6].

Table 1: Overview of the education of the rescue service personnel in Austria [6]

Education level	Theory	Practice
Paramedic “Rettungssanitäter/Rettungssanitäterin”	100 hours	160 hours
Emergency paramedic “Notfallsanitäter/Notfallsanitäterin”	160 hours	320 hours

Paramedics must complete a further education (at least 16 hours) within every two years. In a rhythm of two years, every paramedic must complete a recertification. There the cardiovascular resuscitation skills and abilities, including defibrillation with semi-automatic devices, were reviewed by a doctor. Emergency paramedics, who have acquired the competence of intubation, must check their knowhow from a doctor every second year [6].

In training and further education simulation training has also gained more importance in the medical field [7]. Also the digitalisation offers new opportunities for initial and continuing education [8, pp. 269–270]. In the next chapter simulation training is explained.

2.1.2 Simulation training

According to Koppenberg et al. [7] in simulation training, or simulation-based training the learner can perform certain tasks or activities in various real-world scenarios. The degree of reality depends on the type of simulation. There are low-fidelity and high-fidelity simulators. Low fidelity simulators are usually used to teach the basics of technical skills. An example of a low-fidelity simulator is the intravenous insertion arm[1]. High fidelity simulators are used to practice complex

[1] https://www.mentone-educational.com.au/simulation/clinical-skills-and-patient-care/iv-access-injections/deluxe-iv-training-arm

situations with high authenticity. Referring to Herault et al [9] high fidelity simulators combine part or full body mannequins or humans. They can talk, breathe, blink, and respond either automatically or manually to physical and pharmacological interventions. Simulation-based training is a good possibility to train rare situations or decisions in a safe environment, where it is allowed to make mistakes. Furthermore, it is a good tool to learn new skills.

Advantages of simulation training are repeatability, they are ethical unproblematically and errors can be used as learning experience. Maybe also money can be saved and the training can be standardized [10].

Aside from training with mannequins or humans there is also the possibility to exercise computer-based. The use of interactive technologies like 360-degree videos, virtual reality, mobile devices and sensors are components of such computer-based exercises. Compared with the traditional simulation techniques this kind of training is location-independent and any number of users can train synchronous. Additionally, computer-based exercises provide the trainer with specific information about the performance of the trainee [9].

2.2 Virtual reality/augmented reality

According to Parisi [11, pp. 1–2] virtual reality (VR) allows a person to feel and act on a virtual environment as if the person would be really in the scene. This is going to be reached by tricking the human brain, especially the visual cortex and parts of the brain that perceive motion. According to Izard et al. [12] VR can be divided into two main categories: The first category is a three-dimensional (3D) world which is completely created by a computer. The space for the visualization is calculated in real-time, therefore the camera position is freely selectable. The second category basically consists of a reflection of our reality. This type of VR is created by 360-degree videos. At this type the 3D capacity gets lost, but therefore it gets more realistic. The combination of both categories can be seen as third classification: There are virtual elements created by computer as well as 360-degree images and videos.

Parisi [11, pp. 1–3] explored VR as a fully immersed experience. To reach this immersion some technologies were combined: head-mounted displays, motion tracking hardware, input devices and software frameworks. If one thing is missing, it is hard to achieve a fully immersive VR experience. In particular, development tools (for example Unity3D and Unreal Game Engines) are necessary to develop a virtual experience. VR is a young science, which is strongly driven by the rapid progress of the hardware. VR is used in many areas for example: video games, education, tourism, enterprise applications, live events, web browsing, architecture and real estate. According to Buhr et al. [13, pp. 195–200] a main property of VR is the interactivity. For an immersive experience it is very important that the user can notice the consequences of his actions in the virtual environment. Here the latency plays a big role. Latency is the time which the system needs to react on the input. This reaction should be below the human perception threshold. The greater the latency is, the less unreal the action appears. Real-time capability could also be associated with latency. It means that the graphic output can generate images so quickly, that they are not perceived by the user as single-frame sequences. Depending on external factors, a frame sequence just below 50 Hz repetition rate is no longer directly perceptible. At a 100 Hz repetition rate, a picture is considered flicker-free. But this is often difficult, because a simple perspective change can overcharge the graphic hardware, that it is not able to estimate the answer, because the complexity of the scene is too big. Latencies can occur on different places in a VR-system. The different kinds of latency are a tracking latency, a presentation latency, a simulation latency, a transport latency and a generation latency (Figure 1) [13, pp. 195–200].

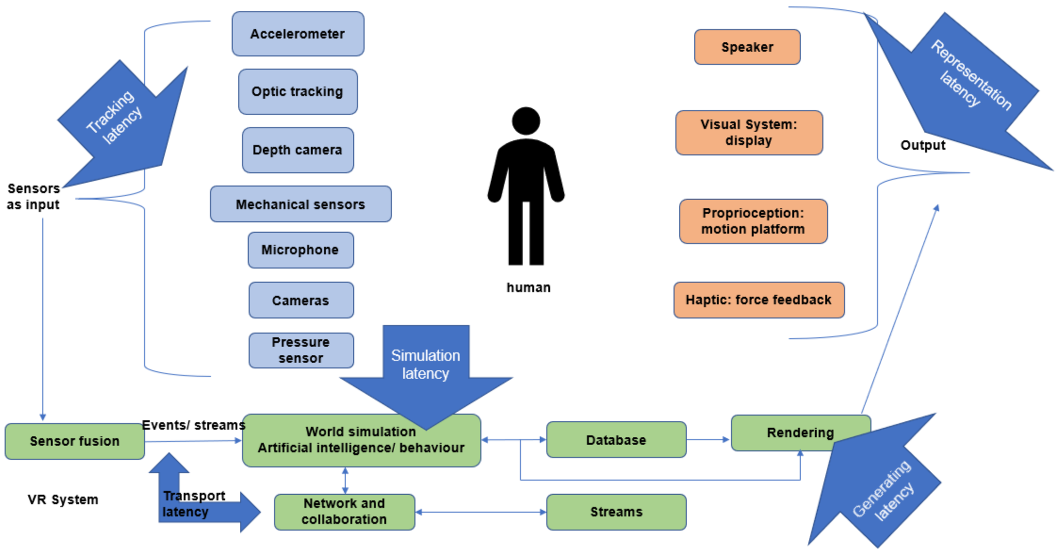


Figure 1: Latencies of VR systems modified by Buhr et al. [13, p. 199]

Broll [14, pp. 245–246] described that the augmented reality (AR) in opposite to VR is a perception of the real world, enriched with additional, artificial information (for example 3D objects, text in real time). AR is also interactive. Mixed reality (MR) is often wrongly used as a synonym for AR. In contrast Milgram et al. [15] defines MR as a continuum, which extends between reality and virtuality (virtual reality) where the ratio of the reality gets less and the ratio of the virtuality gets respectively more. If the virtuality overweights, but is not only virtual, this is called Augmented Virtuality. However, if the ratio of reality is greater, it is AR.

In the next chapter 360-degree videos were described and then the exploration of the four main components of VR follow.

2.2.1 360-degree videos

According to Violante et al. [16] 360-degree videos are video recordings in which the room is displayed in all directions. This 360-degree view results in a totally immersive video. The viewer has the possibility to see everything in this range. As synonyms spherical video or immersive video are used.

Hebbel-Seeger [8, p. 269] described the position of the camera as crucial for the presentation of the event and its complexity. The camera can be situated fix on a point of view or can follow the occur. If the camera follows the occur, it can be linked on a device (for example a bike) or a person. At 360-degree videos there is no room behind the video.

Based on Hebbel-Seeger [8, pp. 269–270] and Violante [16] to record a 360-degree video either a camera with a lens on the top, that captures everything all around or a camera with at least two diametrically opposed lenses is needed. The camera with two lenses represents the room in a 180 x 180 viewing angle. The actual recording angle is 185 degrees so that the two levels can be seamlessly combined to a 360-degree image. This process is called stitching. Stitching analyses the individual recordings and matches them based on the agreements. According to the used camera the stitching process happens in real-time parallel to the record or must be done afterwards with a special stitching software. If the object, which is recorded by both cameras, is nearly situated, this can result in artefacts in the presentation. An example of artefacts are breaks in the edges of the objects. This is also called parallax effect and depends on the software and the hardware (arrangement of the lenses). The smaller the distance between the opposite lenses is, the lower is the parallax effect.

The Samsung Gear 360 – 2017, which was used for the recording of the training video in this pilot study, can record 360-degree video with a 4K resolution [17]. The actual resolution depends on the used end device, in this pilot study Samsung Galaxy S7 (2560 x 1440 pixels) with a head-mounted display was used. According to Hebbel-Seeger [8, p. 271] if a head-mounted display is used, the resolution divides in half. Reason for this is the separate projection for each eye. To achieve high-quality video productions multi-camera systems should be used. With these systems, several cameras are coupled together, and the individual shots are stitched afterwards.

Hebbel-Seeger [8, pp. 272–273] mentioned that 360-degree videos can be watched on different devices like desktop computer, notebooks, tablets or smartphones. The quality of presentation depends on the processing power and the main storage. A special software is required. A distinction is made between server-based and client-based applications. Server-based means that the player and the content were provided by an external server and the request occurs online. For this option a stable and fast internet connection is required. In addition, there are special requirements for the internet browser, which are not fulfilled by all browsers. Client-based means that the content is stored local, therefore a specific software, to play 360-degree content, must be installed on the end device.

Violante [16] described that the selection of the image section depends on the device. With tablets or smartphones, picture selection is done with the swipe of the finger. Computers or notebooks interact with mouse and/or keyboard. Generally, with mobile devices the selection of the image can also occur about the alignment of the device with the 3-axis gyroscope. For a completely immersive experience head-mounted displays can be used. According to Hebbel-Seeger [8, p. 272] such videos are also suitable for streaming and thus make conferences or lectures accessible further away. This requires a very high file transfer rate on the sender and receiver side. There are some experiments to reduce the data volume by compressing the 360-degree content, but this has a negative effect on the image quality.

2.2.2 Head-mounted displays

Parisi [11, pp. 3–4] explored a head-mounted display also as stereoscopic display or 3D display. It is the most important thing in VR, because it transmits a sense of depth and allows a native view control over head and body movements. It was a great challenge to develop a stereoscopic display which is light and comfortable enough to wear on the head. In 2012 Oculus VR introduced the Oculus Rift[2] which was more interesting and affordable for the wider public. The Oculus Rift is a lightweight headset with a stereoscopic display and a head-tracking sensor. The first version of this VR hardware, also known as DK1, had compared with the DK2 a lower resolution of 1280 x 800 pixels [18]. DK2, a newer version of the oculus development kit, provide the user a higher display resolution (2160x1200 pixels), a better performance and a position and orientation tracking [11, p. 3], [19]. In the

[2] https://www.oculus.com/rift/?locale=de_DE#oui-csl-rift-games=star-trek

near future, the Oculus Rift S will be launched on the market with better user and wearing comfort and a resolution of 2560 x 1440 pixels [20].

There are several other head-mounted-displays from different producers with different styles and price categories. According to Mealy [21, pp. 285–286] they can be divided into three types: high-end desktop head-mounted displays, mid-tier mobile head-mounted displays, low-end mobile head-mounted displays. High-end desktop head-mounted displays convince with the best possible immersive experience, but always an external hardware (for example desktop computer) is needed. Examples are Oculus Rift, HTC Vive Pro and Windows Mixed Reality headsets. Mid-tier mobile head-mounted displays are more cost-effective and work mostly with a mobile phone. Therefore, they are portable, but the limited computational power can decrease the immersion. Examples for such devices are the Samsung Gear VR and the Google Daydream. Low-end mobile head-mounted display such as the Google Cardboard are a cheap way to get started and to demonstrate the viewing VR experience with less interactivity. The smartphone serves as a VR system, which can be attached to the user's head with a cardboard spectacle holder.

In this master thesis the mobile headset Samsung Gear VR[3] was used. It was produced by Oculus in cooperation with Samsung and is the lightweight mobile version of the Oculus. Strengths of the headset are the combination of the barrel distortion lens from the Oculus optics with new head tracking technology. As working processor, the mobile phone is put into the headset. The following Samsung mobile phones are compatible: Galaxy S8+, Galaxy S8, Galaxy S7, Galaxy S7 edge, Galaxy S6, Galaxy S6 edge and Galaxy S6 edge+ [22]. The display resolution of the used Galaxy S7 is 2560 x 1440 pixels. The Samsung Gear VR has an own inertial measurement unit included, which is based on the technology of Oculus. This results in a faster tracking and a less latency. An adjustment wheel is available to adjust the interpupillary distance of the device to your own interpupillary distance. Additionally, there is a head-phone jack, a touchpad for input and the volume can be adjusted via the headset. This section is based on [11, p. 19]

According to Linowes [23, pp. 52–54] head-mounted displays make a use of the stereoscopic information which is generated by two images, one image from each eye. The two images were slightly shift from each other, therefore it seems like a parallax. Our brain combines the similarities of the two images, while the small differences in these images convey the sense of depth to our minds. As a result,

[3] https://www.oculus.com/gear-vr/

both images are displayed as a single 3D stereo image. A more detailed information how stereo vision works can be found in a following chapter. Figure 2 shows a screenshot of the 360-degree video and how it looks without the head-mounted display.

Figure 2: Screenshot of the 360-degree video without the head-mounted display

In this screenshot it can be seen that each eye has a barrel shaped view. Reason for this are the two lenses in the head-mounted display. These lenses are very wide-angle lenses, which offer a wide field of view. A distortion of the image is caused (Figure 3). This distortion is also called pincushion effect. This distortion has to be compensated by pre-distorting the image, which is called barrel distortion. Thus, a correct representation through the lenses is possible (see Figure 4). The barrel distortion is made by the graphics software (SDK) [23, pp. 52–54].

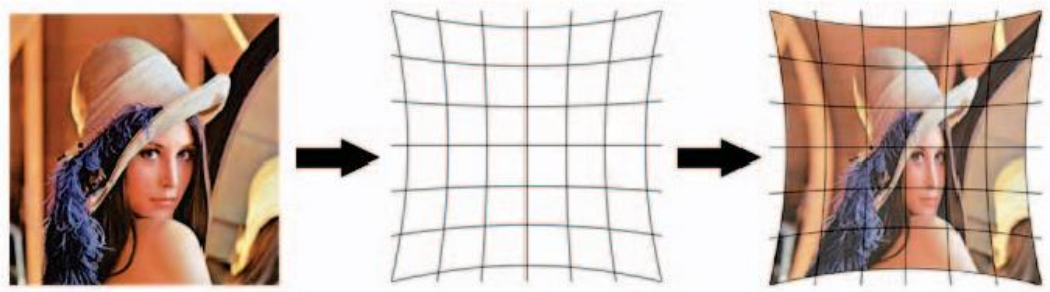


Figure 3: Left side: original image, right side: distorted image [24] ©IEEE

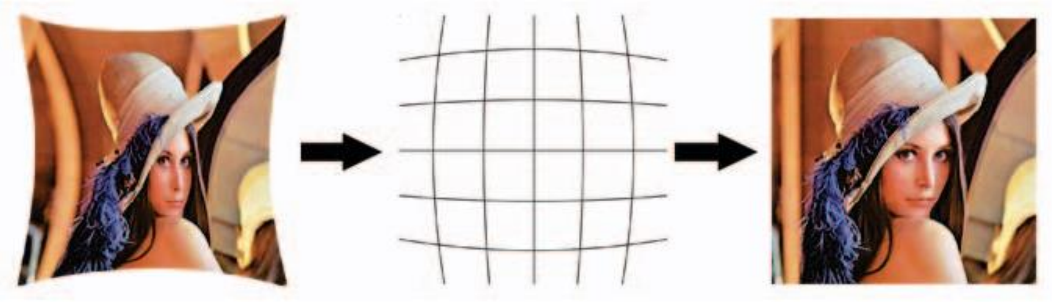


Figure 4: left side: distorted image; right side: correct image after barrel distortion [24] ©IEEE

Based on Parisi [11, pp. 3–4] ideally the stereoscopic display renders an image 60 – 120 times per second. Thus, a perceived lag or latency can be avoided. According to Hebbel-Seeger [8, p. 274] there are limitations in the image quality, because of the maximum of the display resolution and the comparatively close distance from the eyes to the display. Compared with computers the maximum of the display resolution of head-mounted displays reduce in the same field of view around the factor three to four. The reason is the horizontal viewing angle of 90 degree to 110 degree, because the 2,160 x 1,200 pixels of current high-resolution head-mounted displays must fill this view. In contrast the resolution of Wide XGA (1360 x 769 pixels) to Full HD (1,920 x 1,080 pixels) of computers must fill about 30 degree of the horizontal field of view.

2.2.3 Motion tracking hardware

According to Parisi [11, p. 5] motion tracking plays a major rule in VR. Because of the tracked movements of the head and the actualisation of the current scene in real-time, the user's brain believes that it is really in this place. For rapid head motion tracking a high-speed inertial measurement unit was developed. This head tracking inertial measurement units consists of a gyroscope, an accelerometer, and/or a magnetometer hardware. A smartphone also consists of these sensors. Motion tracking is very important, because the perceptual system is very sensitive to motions and therefore a high latency in head tracking can cause nausea and the feeling of immersion can be seriously affected, like the lag in stereo rendering. If the combination of stereo rendering and motion tracking is accurate and if they are updated with enough frequency, a feeling of really being there can be gained.

2.2.4 Input Devices

According to Mealy [21, pp. 37–47] with head-mounted displays the outside world is completely shielded. This increases the feeling of immersion, but it has the consequence that if a situation requires an input, the mouse or the keyboard must be used blind. To solve this, alternative input devices were used. Such input devices are game controllers, motion controllers, hand tracking, eye tracking and much more. The Samsung Gear VR has a full touchpad integrated on the right side. The touchpad can be used for swiping horizontally or vertically, tap on items, toggle volume and get back of content. Currently there is no standard input device. In the future, there will be a big chance in the interaction sector.

2.2.5 Computing platforms

In many cases VR applications run on existing computers or smartphones. The requirements to use an Oculus Rift is a relative modern desktop or a high-powered laptop. But even smartphones offer a good VR experience if they have enough CPU and graphics power.

According to Parisi [11, pp. 6–7] development of VR applications can be done in different ways with native software development kits, game engines and frameworks, with modern web browsers and video players. In a software development kit (SDK), developers will find many helpful resources they need to create VR applications, like documentations, tools, libraries or examples. But often developers prefer to use engines and frameworks. An example for such an engine is Unity3D, also known as middleware. These engines are responsible for low-level details of 3D rendering, physics, game behaviours and interfacing to the devices. Such engines have often a strong cross-platform support, which means that the applications run on different platforms, including desktop and mobile. They often contain integrated development environments (IDE)[4]. VR in the web browser brings two advantages. The first advantage: web technologies like HTML5, WebGL and JavaScript can be used to create VR applications. This maybe leads to faster coding and more cross-platforms. The second advantage is that the existing web infrastructure can be integrated in VR applications, like hyperlinking VR experiences, hosting content in the cloud, provide web data and developing multi user shared experiences. VR experiences can be created with video players in combination with stereoscopic videos, where the real world is recorded. To use this video in VR 360-degree videos are necessary. [11, pp. 6–7]

[4] Tools which support the development

2.3 Perception aspects of VR

How immersive the VR experience is, depends not only on technical aspects, but also how people perceive and process information. With the knowledge of information processing the effect of VR could be better understood and advantage can be taken of restrictions.

For VR technologies the visual, the acoustic and the haptic sense are the most important of the five human senses. Thus, in virtual worlds no other senses are addressed than with conventional desktop environments. Dörner and Steinicke [25, pp. 33–35] explored the simplified information processing of Card et al. [26]: At the human information processing the perceptual system perceives an environmental stimulus. There are memories and processors in the perceptual system. The cognitive system processes the perceived stimuli with the working memory and the long-term memory. The stimuli are interpreted here, and actions are planned. The real action takes place in the motor system (see Figure 5).

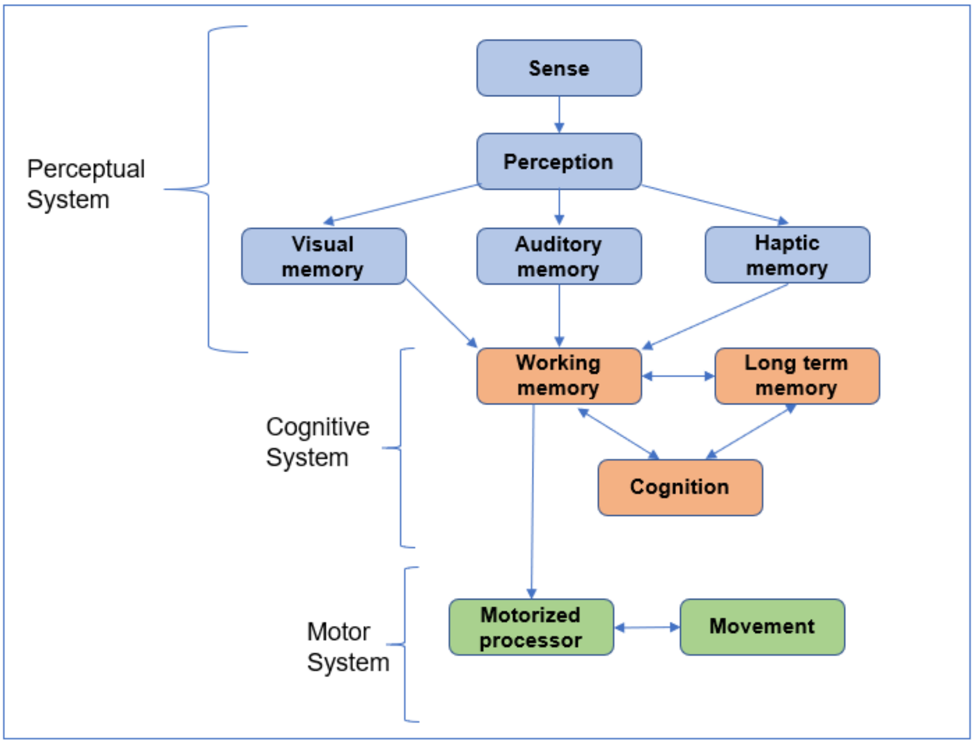


Figure 5. Human information processing modified by Card et al. [26]

A more detailed information about processing and memory is given in the next chapter.

2.3.1 Visual perception

According to Dörner and Steinicke [25, pp. 35–36] the visual system is used for the transmission of optical stimuli. Therefore, the eye plays a major role. In the human eye, light is projected over the lens to the retina. There are millions of photoreceptor cells in the retina. They are divided into rods (approximately 120 million) and cones (six million) [27, p. 27]. The rods detect the brightness and the cones perceive the colours. To perceive the three different tones of colour blue, green and red there are three types of cones. The refracting media of the eye consists physiologically of cornea, anterior and posterior chamber of the eye, lens and vitreous body. It creates an upside down and reversed image on the retina [25, pp. 35–36].

Based on Fuchs [27, p. 26] accommodation is the adaptation of the lenses to the different distances of the viewed objects. The closer an object is, the focal length of the lens must be smaller, to make the image of the subject on the retina sharp. The lens can achieve this by rounding off (by contraction of the ciliary muscle) and thereby increasing its refractive power. On the central point of the retina, there is the fovea. This is the area to see the sharpest, because here are the most photoreceptor cells. According to Dörner and Steinicke [25, pp. 35–36] two to three degrees of field of vision are projected on to the fovea, where the resolution is between zero point five and one angular-minutes under optimum conditions. This point is located only for 250 milliseconds until one second followed by fast eye movement, so called saccade. This functions as a supplementing of the peripheral perception, where the resolution is only one fortieth of the foveal resolution. This pretends to perceive a complete picture.

Dörner and Steinicke described [25, pp. 35–36] the visual perception as the ability to see, organize, and interpret one's environment. The identification of the objects begins in the retina, where the brightness, contrasts, colour and movement of the picture were analysed and edited (for example brightness compensation and contrast enhancement) by the photoreceptor cells. The information is converted in electrical signals and transferred to the ganglion cells. The ganglion cell is always excited by the same photoreceptors, that respond to stimuli in an area of the visual field and transfer the signal to the optic nerve. Via the optic nerve and the “corpus geniculatum laterale“, the signal reaches the visual cortex. The spatial relationships of the receptors remain and help to identify and differentiate between the objects. Through comparison with already stored experiences (scenes linked with body feeling, emotions, smell, sounds and much more) the identification can probably occur.

2.3.1.1 Stereoscopic vision

As mentioned above, an important aspect of VR-Systems is the stereoscopic vision. Because of the two images with small retinal disparities, created by head-mounted displays, the visual system can construct a 3D perception from these images. According to Fuchs [27, pp. 31–36] the phenomena of stereoscopic vision of real life is used. Due to the different perspective of the eyes, the two retinas build two images of the same 3D-object. In Figure 6, A is an object and the eyes are adjusted so that light enters the left and right fovea and the retina (A_1 and A_2). The resulting angle α depends on the inward movement of the eyes to fix the object. This movement is called convergence. The greater the convergence, the greater α is and the closer is the object. β is the measure of disparity and is the angle between the corresponding point of the retina and the actual point of the retina. Corresponding means that the point on the left and right retina is in the same place. If the disparity is zero, then the object lies on the horopter and the visual system can merge the two images into one. The bigger β is, the farther away it is from the horopter. If the horizontal disparity is slight, then the object is in the panum's area and therefore can be merged and perceived as a single image. This is also called binocular vision. If the object is located outside the panum’s area (for example B), the two images are perceived separately. This is called diplopia. Are the objects situated ahead of the horopter, they are called to be converging or in crossed disparity. The objects behind the horopter are diverging or in direct disparity.

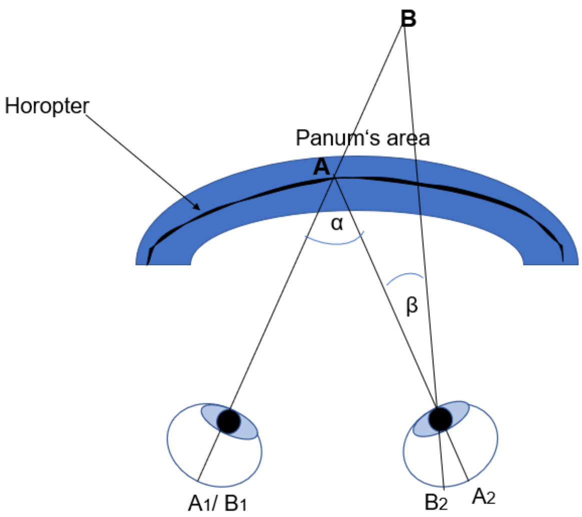


Figure 6: Stereoscopic vision modified by Dörner and Steinicke [25, p. 37]

Based on Dörner and Steinicke [25, pp. 38–39] with head-mounted displays the stereopsis can be manipulated. In Figure 7, the display especially point A is considered. two points N_1 and N_2 are shown on the display. Whereby due to the technology of head-mounted displays, light from N_1 only reaches the right eye and light from N_2 only reaches the left eye. This creates a parallax. Parallax is the distance between N_1 and N_2. The visual system has two options how to react on this situation. The first option: two different points are perceived. It is also common in the reality, that light hits only one eye. The second option is that the visual system believes that the two light stimuli of N_1 and N_2 come from a single point N* in front of the display, which means that N* is the fusion of N_1 and N_2. If a fusion occurs, the point appears to be outside the display. If the order of the points for the left and right eye on the display is reversed, a positive parallax is generated, and the point seems to be behind the display (see points O in Figure 7). According to the chosen parallax, the objects can be in front of the display (negative parallax) or behind the display (positive parallax). This results in a 3D - visual impression. Which option is chosen from the visual system depends on many factors, for example from the distance of the point O* to the display.

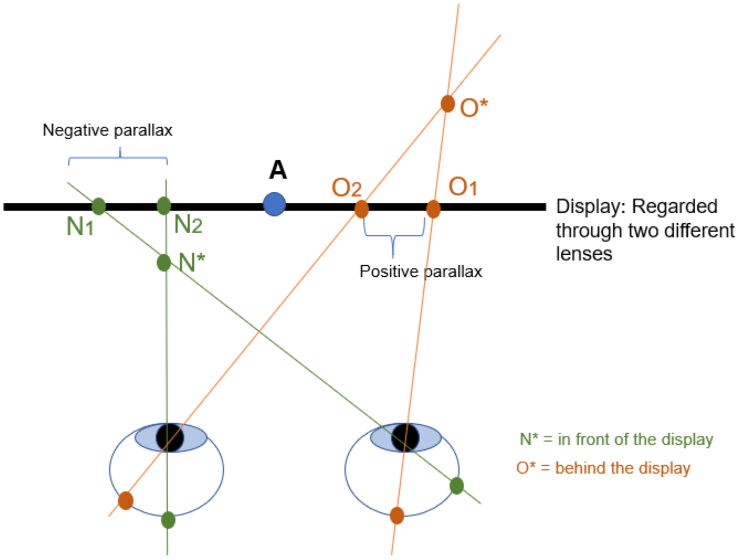


Figure 7: Manipulation of the stereopsis with a head-mounted-display modified by Dörner and Steinicke [25, p. 37]

2.3.2 Space perception

Based on Dörner and Steinicke [25, pp. 39–41] space can also be perceived by the brain through different depth cues. There are three categories of visual depth cues: monocular, binocular and dynamic. In contrast to binocular were both eyes were required, monocular means there is no ensemble playing of both eyes [28, p. 98]. A dynamic depth cues is generated by movement. In addition, the sensation of depth can also be generated on two-dimensional graphics. They were called pictorial depth cues. Furthermore, it can be differentiated if the depth cue helps to estimate the spatial position of an object absolutely or only relative to another object. The distance plays a major role how reliable the depth cues appear. In Table 2 depth cues were listed.

Table 2: Depth cues modified by Dörner and Steinicke [25, p. 41]

Depth cue	Scope	Categories	Determination of position
occlusion	full area	monocular	relative
disparity	up to ten meters	binocular	relative
convergence	up to two meters	binocular	absolute
accommodation	up to two meters	monocular	absolute
depth of field	full area	monocular	relative
linear perspective	full area	monocular	absolute
texture gradient	full area	monocular	relative
relative size	full area	monocular	absolute
known size	full area	monocular	absolute
aerial perspective	over 30 meters	monocular	relative
height in visual field	over 30 meters	monocular	relative
shape from shading	full area	monocular	relative
shadow	full area	monocular	relative
movement parallax	over 20 meters	dynamic	relative
accretion and deletion	full area	dynamic	relative

2.3.2.1 Depth cues

Occlusion or covering occurs when one object completely or partially obscures another object. An example for covering is if a tree covers a house, then the visual system recognizes that the tree is closer to the observer [28, p. 100].

As mentioned above the disparity depends on the distance to the object. The greater the distance from the viewer to the point, the smaller the disparity is. Up to ten meters the disparity is observable, but at two to three meters it is already very low. For virtual worlds, this means that with a distance more than three meters from the observer to the object, the use of stereoscopic displays does not improve the perception of depth [25, p. 40].

Convergence is a binocular depth cue. It is the movement of the eyes when looking at close objects. Because the closer the object is to both eyes, the more they must be turned inward towards the nose. The opposite of convergence is divergence [28, pp. 93–102].

Accommodation is used to focus objects depending on their distance. This is done by the tension of the muscle that changes the focal length of the lens. To focus close objects, more muscle power is required to squeeze the lens. If an object is focused at a certain distance, only other objects in the surrounding area appear sharp. The accommodation is related to another monocular depth cue, the depth-of-field (DoF). It can be defined as a range of distances near the point of focus, where the user perceives the image acceptably sharp [25, p. 40], [28, p. 102].

Linear perspective is based on converging parallel lines that move away from the viewer. It is a result of perspective distortion. The relative size can also be related to perspective perception as objects further away appear smaller. The visual system perceives similar objects with a different size as farther away and not as the objects are smaller. This property can also be related to textures. These depth cues are called texture gradients [25, p. 40].

In the human perception the known size plays a major role. If a scene contains an element of familiar size, it provides a reference point and thus a scale for all other abstract or unknown objects in the scene [25, p. 40].

The depth cue height in visual field refers to the horizon line. The closer an object is to the horizon line, the farther it appears. An example can be seen in Figure 8 a): The square with the letter C is higher located and therefore closer to the horizon line as the quadrat with the letter A. Quadrat C looks farther away [25, p. 41].

The atmosphere not only consists of air, there are also small particles. Hence objects far away seem fuzzy and have a bluish colour (Figure 8 b)). This depth cue is called aerial perspective [25, p. 41].

The lighting of objects gives an information about arrangement in the room. This has two reasons: The first reason is, that shaded objects are more three-dimensional (Figure 8 c)), and the second reason is the shadow. The spatial arrangement of an object can be derived from its shadow. As it can be seen in Figure 8 d) the shadow of the sphere is at the bottom, so they can’t be located at the bottom [25, p. 41].

There are also movement-induced depth cues. This includes the movement parallax. Is an object or the viewer in motion, the light stimuli from nearby objects move faster over the retina than distant ones. For example: Looking out of the window during a train ride, the close trees fly by while trees far away barely move [28, p. 102].

Through movement objects can be covered und uncovered and depth cues can be generated. This is called accretion and deletion [25, pp. 41–42].

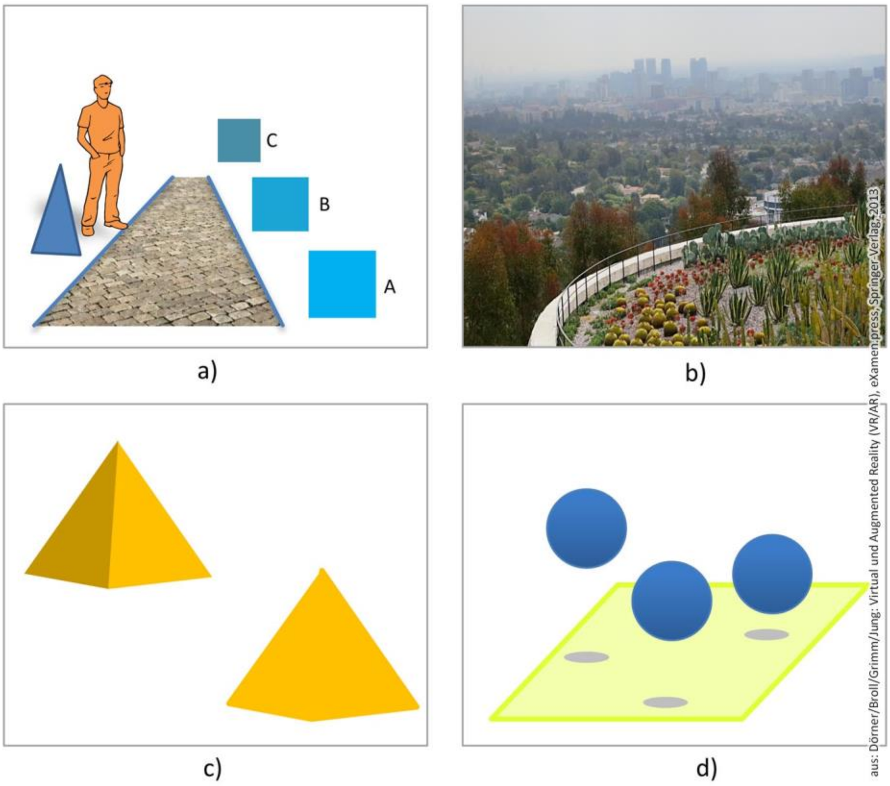


Figure 8: Depth cues: height in visual field (a), aerial perspective (b), shape of shading (c) and shadow (d) [25, p. 42]

Depth cues can depend on each other and the strength of the effect is different. It is very flexible how strongly a depth cue is weighted. On the one hand, it depends on the distance of the object and on the other hand, on the task which must be completed from the observer. For the estimation of the spatial arrangement of distant objects, the movement parallax, linear perspective, texture gradient and shadow are suitable. To grab objects convergence, accommodation and disparity are good depth cues [25, p. 42].

2.3.3 Auditive perception

According to Dörner and Steinicke [25, p. 43] and Hagendorf et al. [28, p. 124,126] at the auditive perception, mechanical corrugations are generated by air and pressure fluctuations (in humans voice it is the vocal cords, which were vibrating) and were transmitted to the ears via the air. The ear consists of the outer, middle and inner ear. From the outer ear, also known as the ear conch, the sound waves are collected and transmitted to the middle ear. In the middle ear are the auditory ossicles, which are named hammer, anvil and stirrup. The auditory ossicles transmit the vibrations of the eardrum, caused by the sound waves, to the inner ear. The inner ear contains of the cochlea with the receptor cells. Through the receptor cells, the mechanical energy is converted into electrical signals. These signals are then routed via the auditory nerve to the auditory centre in the brain. The receptor cells are also responsible for distinction of frequencies. Sound waves with frequencies between 20 and 16000 hertz can be perceived. And hertz means vibrations per minute [29, p. 736]. Spatial listening is much lower compared to visual perception of space. The reason why the listener recognizes the direction of the sound source is that the sound on the way to the two ears undergoes a filtering depending on the direction of incidence. This filtering comes from the reflections and diffractions on the human torso, the head and the pinnae, which is described by the Head-Related-Transfer-Function. In all cases, the measured amplitudes are different depending on the frequency and the sonic delay in both ears and thus can be deduced on the localization. However, distinctness is limited because noise sources are only detected, when they are several degrees apart. Acoustic stimuli can be distinguished at a time interval of two to three seconds.

2.3.4 Haptic perception

Haptics has its origin of the Greek word “háptein” and means to touch and represent sense of touch [30]. Haptics include all activities directly related to touching, sensing and grasping of the property of objects and occurs because of the receptor cells in the skin, in the muscles, in the joints and in the cords. The following senses contribute to this: tactile perception (component of surface sensitivity), kinaesthetic perception/proprioception (depth sensitivity), temperature and pain perception [25, p. 44].

The term "tactile perception" refers to the surface sensitivity of the skin, the sense of touch and sensation. Through different receptors of the skin, various stimuli such as touch, pressure, temperature and pain are perceived. The sensitivity of the region is increasing with the number of receptors. The most important receptors include the mechanoreceptors (for example pressure, contactor vibration), the thermoreceptors (heat and cold) and the nociceptors (for example pain or itching). The function of mechanoreceptors is to convert mechanical forces into nervous excitation. These nerve impulses enter the sensory cortex as electrical impulses and are processed there. Result is the perception of shapes (roundness, sharp edge), surfaces (smoothness and roughness) and different profiles (height differences). An example of the stimulation of the corresponding stimuli would be the vibrating of haptic output devices [25, p. 44].

Depth sensitivity describes the body sensation, which means the perception of stimuli from inside the body. This is achieved by the two perception types proprioception and kinaesthesia. Both terms are often used as synonyms. But proprioception covers the sense of position and the sense of strength. The sense of position gives information about the position of the body in the room and the body-head-posture. The sense of strength provides information about tonicity of muscles and chords. Therefore, proprioception enables to know the position of every part of the body at any time and allows to respond. Kinaesthesia informs about the perception of movement and the movement direction. Proprioception and kinaesthesia are very important in VR because most of the interactions occurs through active movement of the extremities [25, p. 45].

2.3.5 Presence and Immersion

As mentioned above a main aspect of VR is the possibility to generate the illusion of really being in the virtual environment. The user should feel really immersed. According to Dörner and Steinicke [25, p. 46] this feeling is called presence and immersion. Immersion is the degree of immersion depending on objective, quantifiable stimuli, such as multimodal stimulations of human perception. Presence is caused by a high degree of immersion.

According to Slater [31] presence can be divided into two major components. The first component is the place illusion, where the perceptual system believes of really being in another place due to the technical possibilities, because VR systems use the similar methods which were normally used for perceiving. As example the one to one tracking of the body or the head tracking could be mentioned. Reason for this are the sensorimotor contingencies: therefore, the brain believes of really being in that place. The second component is the plausibility illusion. It is the illusion that the VR scenario is really happening. Even though the participant knows that this isn't true. Here the perceived construction is coherent, and the virtual environment reacts to the participant actions. For example: the "person" in the virtual environment looks at the participant. When both components were available, then the sense of presence is really high and the participant probably acts realistically in the virtual environment [31].

2.4 Memory and learning

To get more background information and to understand the memory and the process of learning, these topics were described in the next chapters.

As mentioned in the prior chapter, information is perceived through the senses. According to Frick-Salzmann [32, pp. 2–3] the absorption (processing, categorization), storage and recall takes place in the brain. Through the senses a huge amount of information is recorded. The recording of most impressions is short-lived and is therefore not stored. Only that information which seem to be important is perceived and transmitted via nerve tracts into the brain. Subsequently they are processed. There are various methods for storage. The four most important strategies are: repeating, visualizing, associating, structuring. Storage can also be unconscious. After the information has been processed and saved, it can theoretically be retrieved at any time. Sometimes it can also happen that the requested information is not immediately obvious, but this is completely normal. There are three ways to retrieve information:

1. Free recall: Without any indication, the answer must be retrieved.
2. Recall with indication sign: Facilitation of the recall because of a hint, for example, an initial letter of a word.
3. Recognize: Selection options are available.

The perception and the processing can be insured. Causes are brain injuries, dementia changes of brain structures or genetic conditions [32, pp. 2–3].

2.4.1 Memory systems

According to Gudehus et al. [33, pp. 11–12] the memory consists of different systems which were linked with each other. They are made up of different brain structures and have different tasks with the same aim: Storage and management of information. The memory system can be divided into ultra-short-term memory, working memory and long-term memory. Furthermore, there is a distinction of the long-term memory into explicit and implicit memory system. Both systems have also subsystems. Figure 9 shows the different memory systems, with the areas, which are responsible for the processing. The memory systems are very important for the daily life. Because without them, normal things like speaking, reading or riding a bike would not be possible.

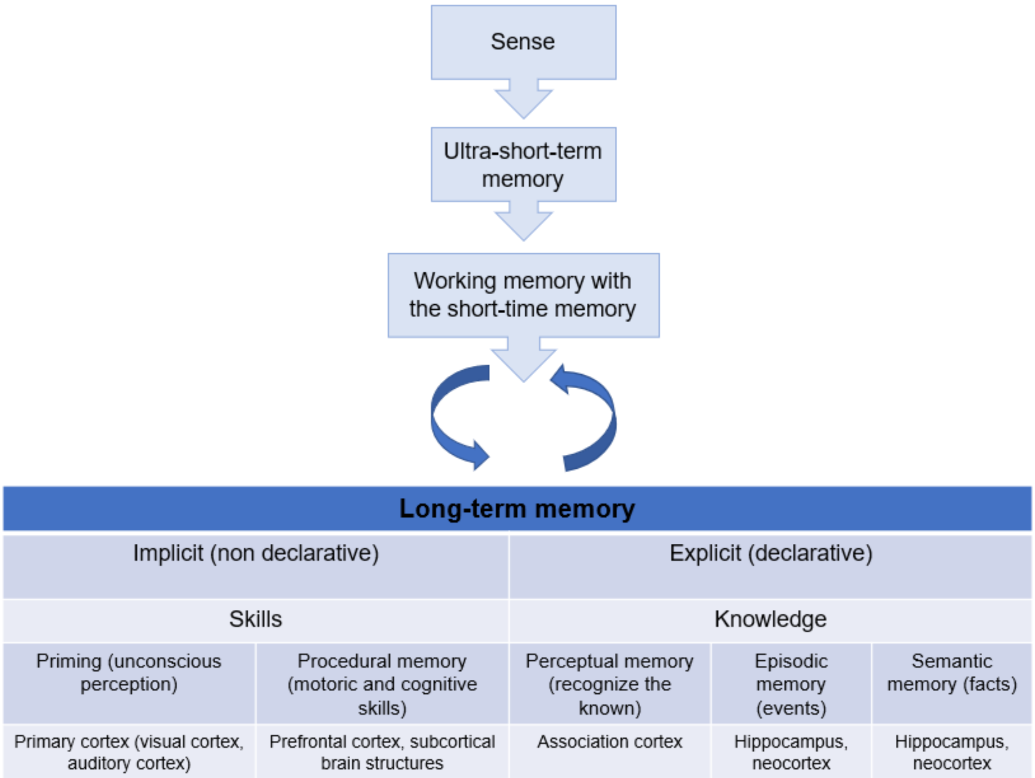


Figure 9: The different memory systems [32, p. 5]

The different memory systems were explained in more detail in the next paragraphs.

2.4.1.1 Ultra-short-term memory

According to Gudehus et al. [33, p. 28] sensory register or sensory memory are used as synonym for the ultra-short-term memory and act as a short-time storage for stimuli and information perceived from the senses. Every sense has its own sensory register. The temporary storage of the sensory register is very large. Frick-Salzmann [32, pp. 4–6] described only if the attention is focused on the information then they were transferred, categorized and stored, because this information is perceived consciously. The transfer takes place from the thalamus to the primary cerebral cortices. In this case the information is stored implicit and represents the biggest part of the information. Only a small amount of the sensory impressions is perceived unconsciously.

2.4.1.2 Working memory

Based on Frick-Salzmann [32, p. 7] the short-term memory is a precursor of the working memory. The information is available for about a minute. In short-term memory, information is kept. In contrast to the working memory, here the information is held and processed. The working memory differs from the other systems, because the memory is limited. The memory retention is seven +/- two information units. Repetition of the information is the requirement to get in the long-term memory, otherwise the information gets lost. The tasks of working memory not only include the processing of information, but also the recall of learned information. This enables the understanding of speech, reading, numeracy, learning and inference thinking. With increasing age, the processing speed decreases, but this can be counteracted by certain techniques.

The expanded working memory was developed in 2000 by Baddeley published in Kühnel and Markowitsch [34]. It was expanded to include the "episodic buffer". Since then, it has been divided into three subsystems and one central executive. Before, it was divided in the two subsystems phonological loop and visuospatial sketchpad. In Figure 10 the components of the working model with their different tasks are listed.

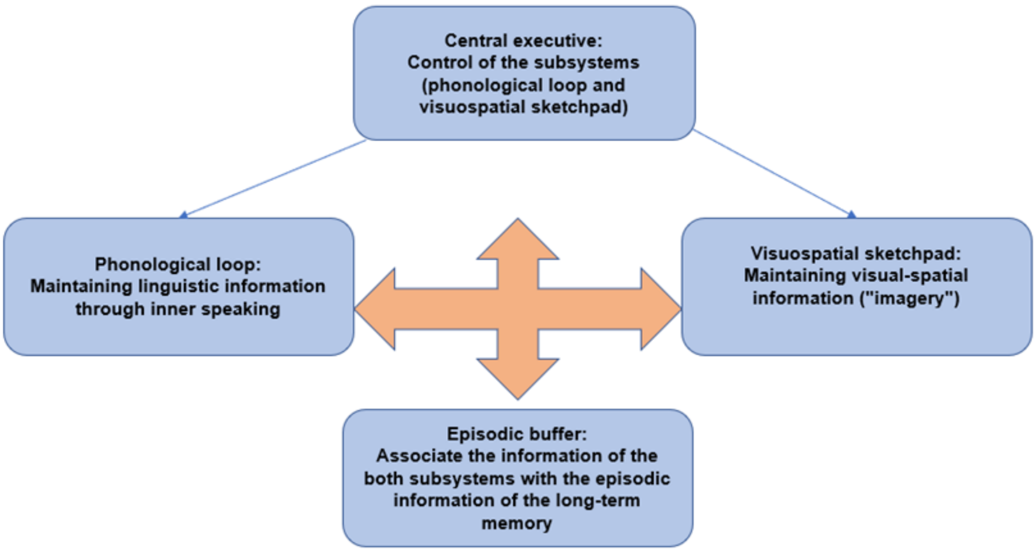


Figure 10: The working memory model from Baddeley in Kühnel and Markowitsch [34]

2.4.1.3 Long-term memory

According to Niegemann et al. [35, pp. 43–44] the long-term memory is responsible for the long-term storage of information, knowledge contexts, experiences etc. stored verbally, pictorially or audibly. Knowledge can be gained memorized or structured and elaborated. The details of elaborated knowledge are linked with each other and schemes are built. Schemes are several small pieces of information combined into a large information unit and stored in the long-term memory. Apart from saving knowledge, schemes also help in the reception of new knowledge by organizing the new information. Learning is the basis of schemes.

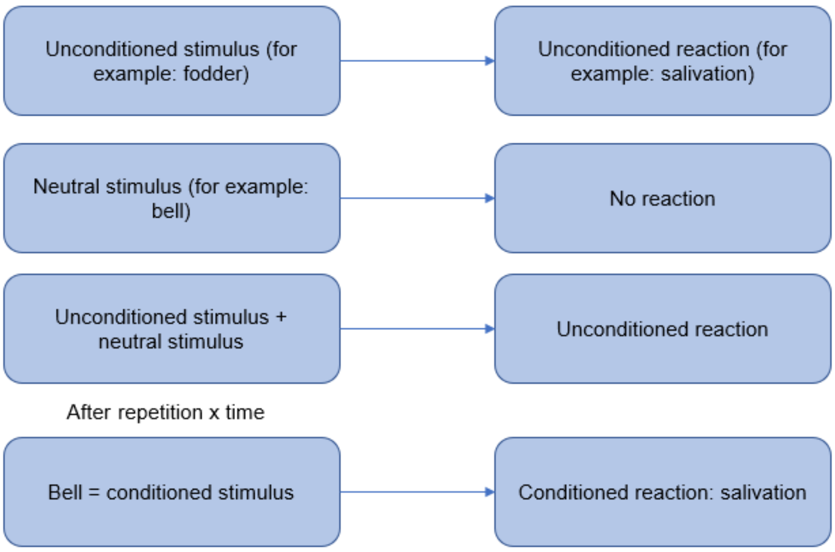
According to Frick-Salzmann [32, pp. 8–11] and Gudehus et al. [33, pp. 12–29] in Figure 9 it can be seen, that the long-term memory is divided into two memory systems: The explicit and implicit system. Another term for explicit memory is declarative memory. Explicit knowledge is knowledge that is consciously perceived, used and transferred to others and is divided into three forms of memory. These three forms are: the episodic memory, the semantic memory and the perceptual memory. The episodic memory is responsible for the storage of events, personal experiences (autobiographical memory) and the spatial and temporal relationship. The semantic knowledge keeps time-independent knowledge like facts, the general knowledge and the meaning of a word. It is more stable as the episodic memory and may also be available for a long time for demented people. The perceptual memory is an intermediate position between conscious and unconscious learning. The perceptual memory is part of the explicit system [34]. Perceptual memory enables the recognition of already known patterns. This is done through comparisons. The recognition of changed structures also takes place without problems. Many stimuli are perceived unconscious. For the processing and storage of these knowledge, habits, learned reactions and experience the implicit memory is responsible. This memory system is very stable and works for people with a severe amnesia. Synonym for implicit memory is non-declarative memory. The implicit memory is divided into two forms: priming and procedural memory. In priming, the unconsciously received information later influences the behaviour, action or performance without being aware of it. The procedural memory includes skills that are automatically executed without thinking. This is achieved through much practice (motor learning, cognitive learning and conditioning). Often both systems were used for learning. In the next chapter the ways of learning were descripted in more detail.

2.4.2 Forms of learning

According to Frick-Salzamnn [32, p. 15] the two different forms of learning are associative and non-associative learning. Non-associative learning does not connect to specific stimuli. Human behaviour is nevertheless influenced. Habituation and sensitization belong to the non-associative learning. Habituation means familiarization. The reaction to the stimuli decreases. The opposite of the habituation is the sensitization. The reaction to the stimuli increases. As an example: If somebody goes through a shocking moment if an harmless event follows this can also be frightened.

Forms of the associative learning are classical conditioning according to Pawlow, operant conditioning according to Skinner, learning on the model, learning by trial and error, learning by reinforcement, learning by insight and cognition, learning by experience and interpretation. In classical conditioning, a reaction is linked to a neutral stimulus (see Figure 11) [32, p. 19].

Figure 11: Classical Conditioning modified by Konecny and Leitner [36, p. 93]



Operant conditioning is also called “learning through success”. Here a reaction is followed by a positive event, so that the probability of repeating this reaction increases. If a certain behaviour is acquired and imitated by observation, this is called learning on the model [32, p. 19].

Kerres [37] described cognitive learning as the acquisition or restructuring of knowledge through the use of cognitive skills by connecting previous knowledge and schemes. The schemes are thereby developed further again and again. The learning success depends on the following facts: How important the content is, how the learner processes the information and how the information is shown. To improve the cognitive learning, it is important how information is prepared and to adapt it to the current state of knowledge. The independence of the learner also benefits from this [38, pp. 67–68].

According to Heider-Lang [38, p. 71] constructivism focuses on the learner and learning is an active construction process in which each learner creates an individual representation of the world. What exactly a learner learns depends strongly on his previous knowledge and the concrete learning situation. Liu et al. [39, p. 110] described constructivism as an important aspect for the education with VR.

According to Liu et al. [39, p. 110] autonomous learning is also important for education with VR. As synonym self-directed learning or self-regulated learning can be used. At this learning theory the teacher acts as a guide. Zimmerman [40] described autonomous learning as a proactive process were the learner sets the learning goals, selects the learning methods, handles the learning progress, and assesses the learning outcomes when acquiring knowledge.

Despite of the different learning theories, there are different types of learning. The visual type learns best by seeing, the auditory type learns best by listening and the conversation type benefits most through communication (speaking and listening). The haptic learning type achieves the most success through its own actions. The verbal learner type learns most easily through concepts and formulas [36, p. 86].

2.4.3 Multimedia learning

Based on Mayer [41] multimedia learning is the way of learning, where text and pictures are combined regardless if the text is written or spoken. Also, the type of picture is not important. It can be static like photos, diagrams, charts and maps or dynamic like animations or videos. The cognitive theory of multimedia learning consists with the three principles of learning. The first principle is that two channels for human information processing are used (see Figure 12). One channel is for the verbal information and one is for the visual information. The second principle is, that these channels were limited in their process capacity. The third principle: The success of learning depends on the learner's cognitive processing during the learning. Examples for cognitive processing are selecting (pay attention on the incoming material), organizing the new information for a connected mental representation and integrating. Integration is the combination of the new information with existing knowledge in the long-term memory. In Figure 12 the cognitive theory of multimedia learning, with the three learning principles, is shown. First, the eyes and ears receive text and images for a short time in the sensory memory. After that, the selected information is transferred to the working memory via the correct channel. It keeps the information separate in the two channels and allows active processing of the new information. The selected information is organized and combined into a mental model (integration). Only when a visual as well as an auditory model is available, the both models can be combined, supplemented and linked with the prior knowledge retrieved from the long-term memory.

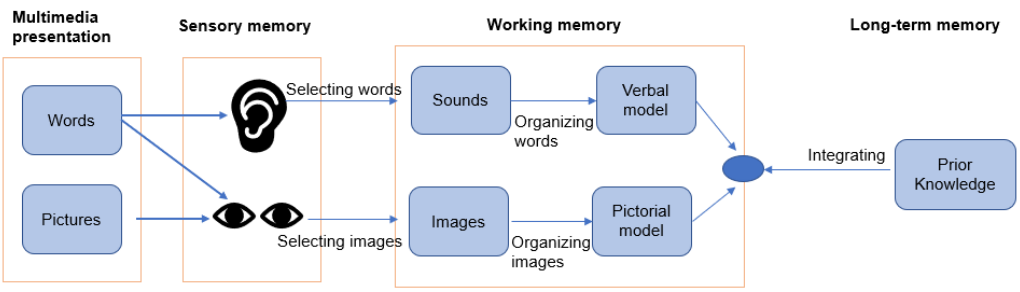


Figure 12: Cognitive theory of multimedia learning modified by Mayer [41]

According to Moreno [42] also the haptic sense is part of the cognitive theory of multimedia learning, because the sensory memory receives information about shapes, sizes or surface structures of objects, through the haptic sense.

Due to the different multimedia modes of VR Liu et al. [39, p. 110] mentioned that also attention on the cognitive load theory (CLT) should be paid. The CLT is a theory of cognitive load, during learning and processing of learned things. Because in case of mental overload the capacity of working memory overruns and the mental processing will be disrupted.

According to Niegemann et al. [35, p. 45] in the CLT the working memory is defined with a limited capacity. The acquisition of new knowledge takes place simultaneously with the retrieval of existing knowledge from the long-term memory and transfer into the working memory. There the combination and supplementation of the knowledge takes place. The CLT distinguishes between three different loads: intrinsic cognitive load, extraneous cognitive load und german cognitive load. Intrinsic cognitive load depends on the learning tasks. The difficulty of the task, the complexity of the task or/and the scope of the learning task play a major role. Extraneous cognitive load refers to the design of the learning material. German cognitive load is defined as cognitive load for the pure acquisition of knowledge.

Referring to Mayer [41] the biggest problem of multimedia learning is, that they cause the learner to engage in extraneous processing. This leads to an overload of the capacity of the working memory but prevents the establishment of appropriate cognitive representation. Therefore 5 principles for reducing extraneous processing and three principles for managing essential processing were defined, which can be seen at Table 3 and Table 4.

Table 3: 5 Principles for reducing extraneous processing [41]

Principle	Definition
Coherence	Extraneous material should be reduced or excluded.
Signalling	Important information should be highlighted.
Redundancy	On-screen text should not be added to narrated animation. The learning success is better from animation and narration than from animation, narration and on-screen text.
Spatial contiguity	Corresponding words and pictures should be placed near to each other.
Temporal contiguity	Simultaneous narration and animation.

Table 4: Three principles for managing essential processing [41]

Principle	Definition
Segmenting	Learning content should be provided in learner-paced segments.
Pretraining	The learner should already know the names and characteristics of essential components.
Modality	Spoken text is better for understanding than printed text.

These principles were partly used in the developed 360-degree video of this pilot study.

2.4.4 Electronic learning

The term electronic learning, shortly e-learning, is used inconsistent in the literature and therefore can be seen as a hypernym for all forms of learning, where information and communication technologies (like Internet, computer, mobile phone, video, and so on) are used to support teaching and learning activities. Defining the term clearly is difficult, because of the different terms which were used as synonyms like multimedia learning, media-based learning, online learning and e-education.

Compared with common learn patterns, e-learning is characterized by special features. The learners are not bound to any place, it can be learned stationary or mobile. It can be integrated in the common learning concept or can be an independent way of learning. It is possible to learn alone or together with others. The exchange can be synchronous or asynchronous. In addition, features are produced due to the technological component. Key words are multimedia, multicodality, multimodality and interactivity. The combination of text, audio, graphics or motion pictures enables a dynamic or a static information transmission. Multicodal means that different symbol systems or coding such as e.g. language and images, are used. E-learning applications are anchored multimodally. This means that they address different senses. Mostly, the auditory and visual sensory channels are affected. These aspects can positively affect the processing of the learning content which in turn strengthens the knowledge. These aspects also enable a different presentation of the learning content, for example authentic situations or different perspectives. If the user becomes active, it is a way of interactivity. A distinction is made between different degrees of interaction. As a low degree of interaction is the operation (stop, back and forth) of videos. Discussions, giving feedback, creating visualizations, answering questions and changing content are higher-level interaction options. Learning strategies and learning experiences are thereby positively influenced [38, pp. 50–51].

There are many different options (Table 5) to use electronic media for learning purposes. In the selection, attention must be paid to the goals, target group and requirements of the learning process. The learning success depends not only on the technical aspects, also the selected didactics is important.

Table 5: E-Learning scenarios [38, pp. 52–57]

Options	Description of the option
Tutorials	To transmit learning content.

Blended learning	Combination of e-learning and presence lecture.
Content-Management-Systems	Systems for creating, managing and researching learning content. Different rights for the users can be determined
Learning-Management-Systems	For the creation, provision and editing of learning content and for the communication and collaboration. Further possibilities are the documentation of learning progress and the integration of course data, wikis and so on. It can serve as an interface to other systems. Different user rights can be determined.
Learning-Content-Management-Systems	Combination of both systems: for managing and retrieving learning content, including communication and collaboration tools.
Personal-Learning-Management-Systems	Knowledge and learning portals. Web-based applications which can be compiled according to the needs.
Games	Experience learning playfully where tasks and challenges must be mastered.
Virtual classrooms	Like conference systems, where a synchronous interaction and communication is possible.
Virtual learning environments	The learner “enters” a 3D learning environment.

2.5 VR in education

Slater et Sanchez [43] defined five aspects why VR positively affects the education:

1. The abstract can be transformed to concrete perceptions and experiences.
2. Despite of the observation, the learner can also action by doing something.
3. Situations or things, which are difficult, infeasible or impossible to train with common learning environments, can be practical trained.
4. Changes of the reality can be investigated.
5. VR can exceed the limits of reality.

According to Slater [44, pp. 24–25] VR can also address the implicit learning. Based on the recognition of Masters et al. [45] learning by observation and without explicit verbal instruction have a positive impact on the multitasking of surgical operation skills. This positive effect can also be used for paramedics.

2.5.1 Training first aid and reanimation in virtual reality

In many contexts it is too expensive to provide for example more first aid mannequins or training defibrillators. According to Bucher et al. [46] this is not the only disadvantages of training with mannequins. One disadvantage is that the location and the time must be determined in advance. It is often time-consuming and not all participants have the opportunity to actively train with the mannequins themselves. A VR training could counteract this problem. Therefore Bucher et al. [46], developed a VR application called VReanimate. Aim of the application is teaching and training of first aid in a safe location and time independent environment. It can be used in the educational sector as well as in the private sector. Thus, an increase in the number of first responders can be achieved. This is also achieved by avoiding particular parameters like exclusion factors (such as text-based instructions and expensive utensils) and other language barriers caused by high-stress situations. The VR application is non-textual and can be used as an action guidance.

There are many other publications and studies, which show the advantages of using VR in medical-related procedures. As an example laparoscopy was trained with VR in Huppert et al [47]. In this application the main steps of the procedure are shown and prepare the user for stressful situations. Moore [48] described immersive VR as a good possibility to support the active construction of knowledge. Because of the user-controlled, realistic environment, where the learning theories constructivism and situated learning were intensified. Another advantage mentioned by Moore [48] is, that nowadays the VR hardware is really good, and a high degree of immersion can be achieved. This results in a great first-person experience. Bucher et al [46] described another positive aspect, that in many VR applications beside audio and visual perception, kinaesthetic is addressed as well. This especially has a positive effect on learning goals, when not only factual knowledge but also processes must be learned.

Dawley and Dede [49] described VR as a good possibility to create situated learning experiences. Because of the authentic learning situations created by VR, a personal and practically oriented learning context arises. Situated learning is often used for process-orientated learning. Using VR in context with situated learning gives the learner the opportunity to experience the situation from a first-person view. The learner can act and try things in a safe environment and can get feedback in many different ways. The learning tasks can be repeated, which is often not possible in other learning environments due to the costs. According to Bucher et al. [46] the training in a safe environment is especially in the emergency sector very important. Making difficult decisions can be practiced, being able to react calmly and more experienced in case of emergency.

The application VReanimate II includes tutorials, exercises and a more advanced training which can be selected through coloured buttons. Each possibility can be repeated as many times as wanted and can be used for practicing knowledge or gain new knowledge. For the application Bucher et al. [46] paid attention to the following design goals:

- Providing an authentic context of the learning content similar as it would appear in real life and authentic activities
- Offer access to expert performances and the modelling processes
- Offer multiple roles and perspectives
- Knowledge should be generated through collaboration
- Give feedback and support at critical times
- Generate a formation of the abstraction through reflection
- Tacit knowledge can be generated through articulation
- Learning can be evaluated through the assessment of the exercises

Regarding other recommendations for the development of interactive user interfaces, there have been some contradictions with the situated learning theories. For example Shneiderman and Plaisant [50] recommended to provide informative feedback for every working method of the user or give the user the opportunity to put some actions back. According to Bucher et al. [45] both recommendations would reduce the realism of the learning situations.

In VReanimate the feeling of really being there is achieved through haptic, auditive and visual feedback. Human noises, for example breathing, if the user gets closer to the patient, should stimulate the auditive perception. Vibrations of the input controller provide the haptic feedback. This is used for example, when touching a patient. The visual perception is supported by a stereoscopic, 3D display. To keep the cognitive load low, the interaction possibilities were marked [46].

For the evaluation of VReanimate 22 test persons were recruited. The aim to teach applicable procedural knowledge related to first aid and reanimation, by means of a situated and non-textual design approach, could be potentially achieved. The results indicate that the situated-VR approach works better to learn sequences of actions rather than declarative knowledge. Due to the small test group no clear statement can be made [46].

2.5.2 360-degrees interactive videos in patient trauma treatment education

Herault et al. [9] also detected the requirement of an interactive learning environment, which enables the education, training and assessment of rare situations, to ensure the competence among emergency personnel. Therefore, an immersive, interactive 360-degree video was developed. The video is displayed via a web browser (see Figure 13). Content of the video is a realistic case in the trauma treatment in an emergency department. The video contains interactions to act and respond. To draw conclusions based on the navigation and interaction, these were stored and later analysed. Herault et al. [9] described hotspots as a good opportunity to make videos interactive. Violante et al. [16] defined hotspots as specific areas in the video, with which the user can interact and when they are clicked or tapped a specific event is triggered. Herault et al. [9] used hotspots to ask content related questions in combination with educational medical theory or previous knowledge of trauma treatment. For the questions, html content was used. The questions were displayed in a specific moment of the video scene. There are three videos. All users start with the same video. Depending on the answer of the questions, the video with the stable patient (right answer) or the video with the instable patient (wrong answer) is shown.

For the evaluation of the video two professional groups were called. 17 test persons from a specialist nursing program (advanced level) and four medical experts. All test persons found the interactive video very valuable and authentic and they agreed that using the tool had a positive contribution to the education of nursing students. Due to the recording of the study, it would be a good option to implementing a screen recording functionality and using the in-built webcam of the screen to record the interactions with the video and with other participants.

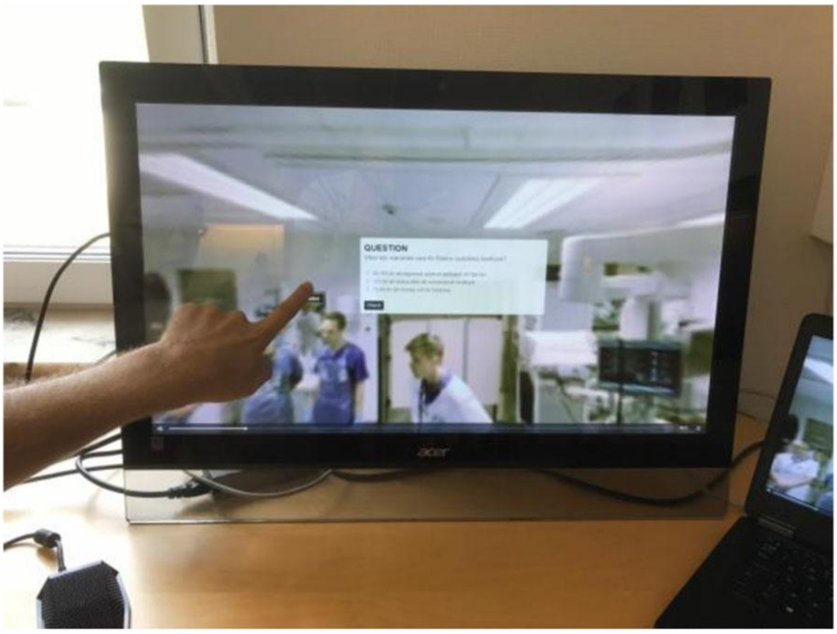


Figure 13: Web interface of the 360-degree video from Herault et al. [9]

3 Development of the 360-degree training video

For paramedics it is important to execute the correct steps in different emergency situations. The appropriate reaction and treatment must be learned and trained by as many people as possible. As already mentioned in the previous chapters, 360-degree videos obtain as a good learning method. Because of this, a 360-degree video for the training of paramedics was developed and afterwards quantitative evaluated. As study design a randomised pilot study with printed questionnaires was chosen. More details about the pilot study were given in the next chapter.

Following the review of the short ethics vote, it was decided that no review by the ethics committee was required.

3.1 Design of the scenario

According to Flake and Runggaldier [51, p. V] experiences in emergency medical service can't be gained from learning of facts. They must be acquired through practical activities. Case studies are a good opportunity to prepare for different situations, to internalize the workflow and to be able to react better. Therefore, a case study was used as content for the 360-degree education video. Also Bucher et al. [46] described in his study "VReanimate II: training first aid and reanimation in virtual reality" that a good success in the acquisition of the right steps can be achieved through VR trainings.

The scenario is a classical situation that any paramedic can encounter. It was designed according to the case study "craniocerebral trauma" of Flake and Runggaldier [51, pp. 46–51].

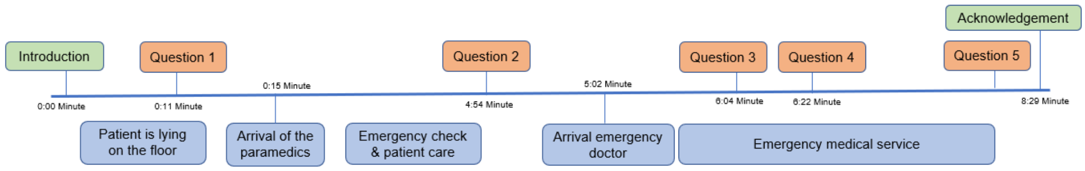


Figure 14: Training video content

In Figure 14 the content of the training video is shown. The blue events below the line were recorded with the 360-degree camera. The events above the line are the hotspots inserted with Unity. As mentioned above and according to Herault et al. [9] hotspots are a good possibility to make the 360-degree video interactive. Therefore, similar as in the study of Herault et al. [9] as hotspots questions were used, which were displayed in a specific moment of the video scene. Learning by observing is the common part of the 360-degree video. The observer should get familiar to the correct steps for the care of a trauma patient. The aim of the questions is to link and consolidate the knowledge by combining the existing knowledge with the seen.

Content of the 360-degree video is a young woman, who fell from a ladder and suffered a severe head injury. The two paramedics first reach the place of action. The doctor arrives later. Then the first question appears, which can be seen in Figure 15. This is the way as it looks like in the video. All five questions offer three options and the video always stops during this time. The selected answer is highlighted in green and then have to be confirmed, with the touchpad on the head-mounted display.

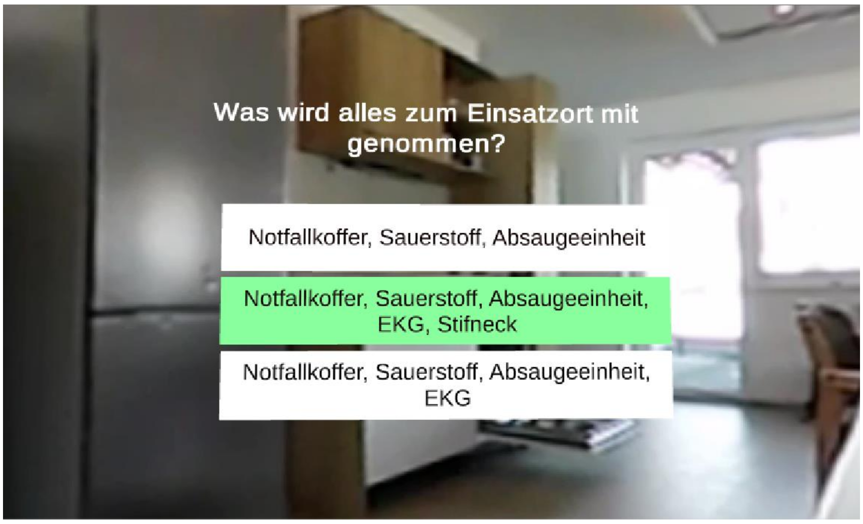


Figure 15: First question

Depending on the answer, either „Right answer" (Figure 16) or “False answer "and the correct answer (see Figure 17) appears.

Figure 16: Screenshot if the right answer is chosen

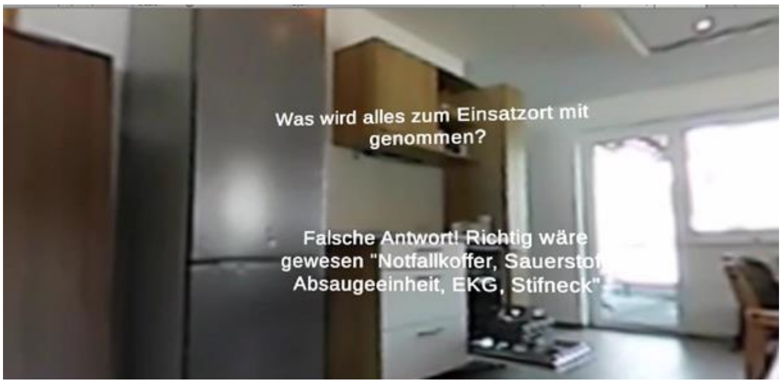


Figure 17: Screenshot if the wrong answer is chosen

After the rescue team has gained an overview of the situation, initial care started. Here, special attention should be paid to the traumatological emergency check and the attachment of the cervical spine splint. The vital parameters are determined, oxygen was given to prevent hypoxia and the wound was treated. The paramedics should then have a suspected diagnosis on his/her mind. The learners must therefore answer a question regarding the suspicion diagnosis. Feedback takes place immediately after answering the question. After the arrival of the emergency doctor, the determined parameters are communicated to him. Based on these values, the learner must answer a question again. The content of this question is the assessment of the severity of craniocerebral trauma. Which have to be determined based on the Glasgow Coma Scale (Table 6). The given points were counted and the result is a supply directive [51, pp. 46–48]. But the schema is not explained in the 360-degree video. The paramedics should know the classification by heart. If they don't know it, the video contains the suggestion, that the video should be stopped to search in the Internet about the Glasgow Coma Scale. This is intended to encourage the learners to study on their own.

Table 6: Schema for the severity classification of craniocerebral trauma [51, p. 51]

Glasgow-Coma-Scale		
opening the eyes	spontaneous in speech for pain stimulation no answer	4 3 2 1
verbal response	orientated dishevelled “word salad" unspecific sounds no answer	5 4 3 2 1
motor response	obeyed prompt targeted pain relief normal bend protection diffraction synergisms stretch synergisms no answer	6 5 4 3 2 1
Total score: **15-13 points:** light craniocerebral trauma, no specific measures are required **12-9 points:** moderate craniocerebral trauma, conspicuous patient, close monitoring of vital parameters and emergency call are necessary **8-3 points:** the patient is acutely endangered; close monitoring of vital parameters, stable lateral position and preparation of intubation and resuscitation, transport with emergency doctor accompaniment		

Then the question “What measures should be taken in case of a severe craniocerebral trauma?" follows. The protection of the individual vital parameters has the highest priority and were continuously measured. One paramedic prepares an infusion, while the other paramedic begins to prepare all necessary utensils for a possible intubation. Intubation and ventilation cannot be ruled out due to the continuing disturbance of consciousness. A venous access is made by the doctor and blood for the laboratory is taken, to be able to determine haemoglobin, haematocrit and blood group in the hospital as soon as possible. In addition, the blood sugar is measured, because at every consciousness a hypoglycaemia must excluded differential diagnostical. One paramedic prepared the medication, which the doctor had required. A crystalloid Ringer-Solution is connected by the doctor, which only runs to keep the vein open, since there is no explicit shock symptomatology [51, pp. 48–51]. Then another question is displayed and afterwards the 360-degree video ends to limit the video time. In this question, the attention of the learner should be tested, because the medical suction device was left and is very important at an intubation readiness. The learner can choose between: nothing left, oxygen mask and medical suction device. The transport wasn't displayed in this education video, because according to the principles of multimedia learning of Mayer [41] the learning content should be segmented (see Table 4 in chapter 2.4.3).

3.2 Production of the 360-degree video

For the 360-degree video the simulated scenario was recorded with a "Samsung Gear 360 – 2017" camera. The fisheye lens of the "Samsung Gear 360" allows to create 360-degree videos and 360-degree pictures with a single shot and can be operated either directly on the device or remotely via Bluetooth or Wi-Fi with the mobile device. After the creation of the video, the 360-degree video was stitched and cut with the Action Director[5]. This is an open source stitching software provided by Samsung. The addition of the audio was also done in the Action Director. To get an immersive experience, the 360-degree videos should be played with a head-mounted display. As head-mounted display a „Samsung Gear VR" was used. To render the 360-degree video on a head-mounted display it was processed in Unity. The questions were also developed in Unity. In the next chapter the development in Unity is explained in more detail.

3.2.1 Development in Unity

Based on the Unity documentation[6], the Android environment setup was done. First, the Android Build Support must be installed, which was directly installed with the Unity Editor. For the development of the interactive 360-degree trainings video Unity 2018.3.11f1 was used. The second step was the Android SDK installation by using the command line tools. The third step was to enable the developer options and afterwards activate the USB debugging on the device, where the 360-degree video should be built and run. The Android SDK path in Unity was located when the project was first built. After the project was created, the 360-degree video was copied to the project assets. Then the GVR SDK for Unity[7] was downloaded, which

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[5] https://de.cyberlink.com/learning/video/670/einf%C3%BChrung-in-gear-360-actiondirector

[6] https://docs.unity3d.com/2018.3/Documentation/Manual/android-sdksetup.html

[7] https://github.com/googlevr/gvr-unity-sdk/releases

enables interaction with the UI elements in Virtual Reality environments. The GvrEventSystem, GvrControllerMain, DemoInputManager and the GvrEditorEmulator were added from this asset to the scene. These were the necessary objects for the interaction.

Based on the tutorial video on YouTube[8], a video player object was built. And the 360-degree video was connected with the video player (see Figure 18). To render the 360-degree a render texture was built. As can be seen in Figure 18 at the render mode the render texture must be chosen. At the render texture some settings have to be done (2D, and the resolution of the video under size: 2560 x 1280, no depth buffer). Then a panoramic skybox material was generated, which was dropped into the scene view.

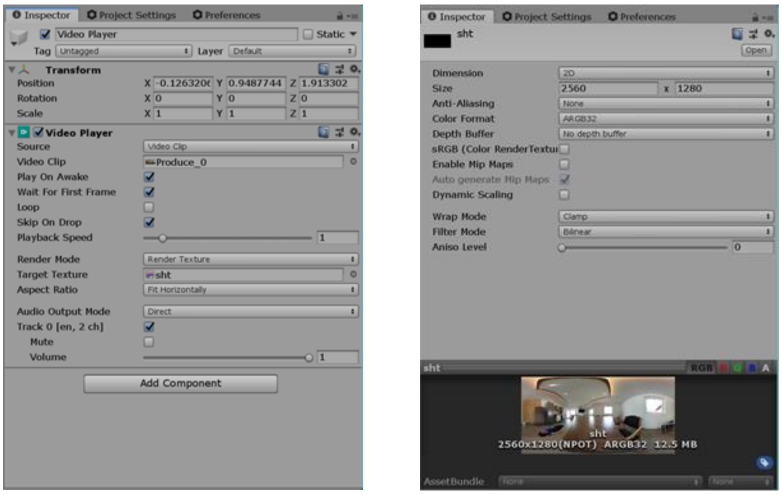

Figure 18: left side: Video player settings; right side: render texture settings

Afterwards a new game object was produced and a script for the questions and answers was built. This script contains the objects for the answers, the questions, the feedback, the object where the seconds was given, when the question should appear. Further content of the script are some functions with if-statements for the behaviour of the question, behaviour for the correct answer and behaviour for the wrong answer. An excerpt of the used script is shown in Figure 19.

8 https://www.youtube.com/watch?v=hmCxXFY-JHs

```
public void AnswerWrong()
    {
        answerFinished = true;
        videoplayerObject.Play();

        Answer1Button.SetActive(false);
        Answer2Button.SetActive(false);
        Answer3Button.SetActive(false);
        FeedbackObject.enabled = true;

        FeedbackObject.text = "Falsche Antwort! Richtig wäre gewesen \"" +
GetCorrectAnswer() +"\"";
    }

    public void AnswerCorrect()
    {
        answerFinished = true;
        videoplayerObject.Play();

        Answer1Button.SetActive(false);
        Answer2Button.SetActive(false);
        Answer3Button.SetActive(false);
        FeedbackObject.enabled = true;

        FeedbackObject.text = "Richtige Antwort!";
    }

    private string GetCorrectAnswer()
    {
        switch(correctAnswer)
        {
            case 0: return Answer1;
            case 1: return Answer2;
            case 2: return Answer3;
        }
        return "";
    }
```

Figure 19: Excerpt of the question/answer script

Some game objects and TextMeshPro Text objects were built and referenced in the inspector to the question and answers in the script. To run the app on the Samsung Gear VR the Oculus must be added in the XR settings at the Virtual Reality SDK’s. In Figure 20 a screenshot of the project scene in Unity is shown.

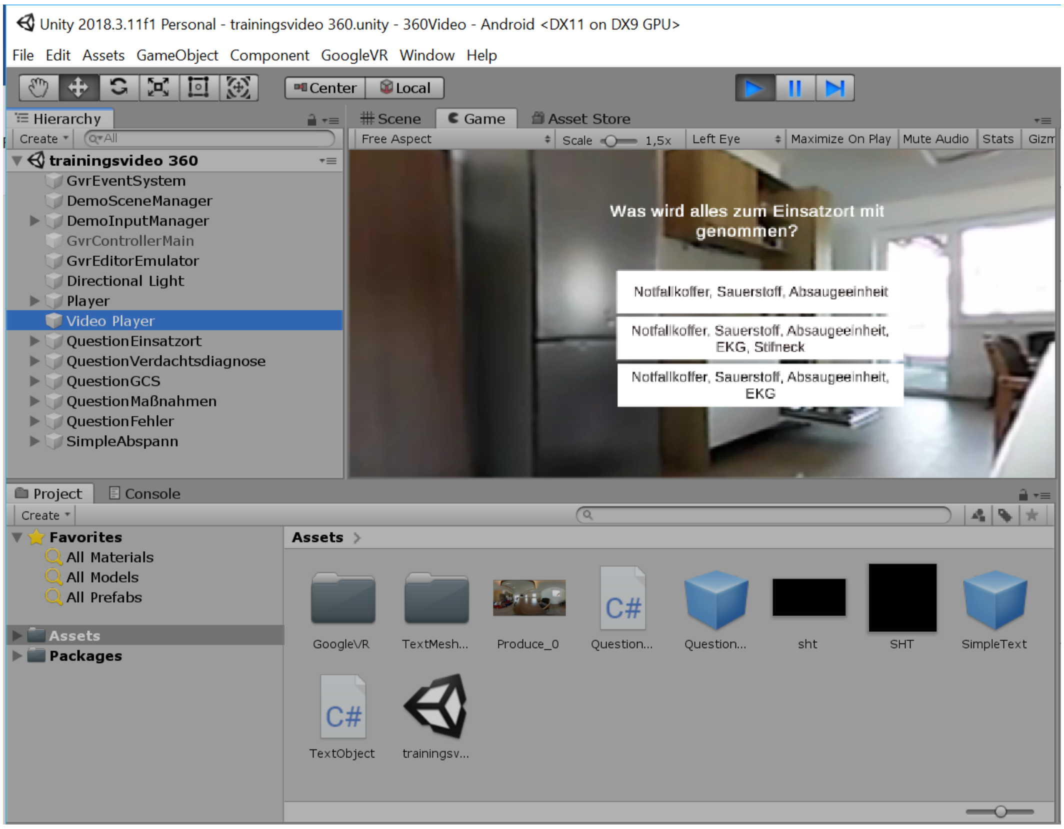

Figure 20: The project scene of the 360-degree video in Unity

4 Pilot study

In the pilot study, ten paramedics evaluated the 360-degree training video. Due to the small sample size, only the pre-acceptance can be confirmed or rejected, and a hypothesis can be generated. This can be investigated in a secondary study with more study participants.

4.1 Participants and experimental setup

For the pilot study ten participants were recruited, between the age of 18 to 30, six males and four females (general information about the participants is shown in Table 7). The average age was 24.3 years. As inclusion criteria the following parameter were defined: trained paramedics, age between 17 and 35 years, working experience under twelve years, no emergency paramedics, participants are only allowed to watch the video for the first time. 20 % of the participants had prior experience with 360-degree videos. Three participants had prior used a head-mounted display. All participants watched the 360-degree video with the head-mounted display "Samsung Gear VR" and as processing unit the smartphone "Samsung Galaxy S7" was used. The technical data of the display are five point one inches with an active matrix organic light emitting diode (shortly AMOLED) with 2.560 x 1.440 pixels.

Table 7: General Information about the participants

Participants	
Gender	
male	6
female	4
age	
17 – 20 years	1
21 – 24 years	5
25 – 28 years	2
29 – 32 years	2
33 – 36 years	0
Working experience	
0 – 6 years	7
7 – 12 years	3

Prior usage of a head-mounted display	
yes	3
no	7
360-degree video experience	
yes	2
no	8

4.2 Procedere

Every participant got a brief introduction (approximately two minutes) about the procedures, the aims of the study and how to use an interactive video with the head-mounted display. No trials or videos of how participants could perform any specific task were shown because their natural behaviour and reactions should be observed. The execution took place in a quiet room, where only the participant and the tutor were located. Then the participant executed the interactive 360-degree video, while a tutor was the whole time available for important questions and to notate special reactions. Every participant had the possibility to watch the video twice, but nobody took the opportunity. After the participants watched the 360-degree video, they got a post-session questionnaire about their experience with the interactive 360-degree training video. This questionnaire is described in more detail in the next chapter. The mean time of the sessions was 15.2 minutes. In this time also the completion of the questionnaire is included. The pure video duration is 8. 48 minutes. The answers to the questions in the 360-degree video were not recorded, as the evaluation of the video was in the centre of attention and as it should not be stressful or an exam situation for the participant.

4.2.1 Questionnaire

The questionnaire to evaluate the video consists of two main parts. At the first part some personal data (gender, age, since when the test person is a paramedic, previous use of HMD-displays, experiences with 360-degree videos) were collected. The second part is the adapted technology usage inventory (TUI) questionnaire.

The TUI questionnaire was developed by the “Information- and Communication technology Applications: Research on User-oriented Solutions” (ICARUS) team of the university in Vienna, to be used for research purposes in the field of technology acceptance research. The procedure is designed to help researchers to evaluate developed technologies for older people as well as for people over 18 years. TUI is used to record technology-specific and psychological factors that contribute to the actual use of a technology. The TUI questionnaire contains the following eight scales: Curiosity, anxiety, interest, usability, immersion, usefulness, scepticism and accessibility [52].

This questionnaire was taken, because it can be used for a user-centered evaluation of new technologies. Based on the TUI questionnaire, 17 statements and an optional field for personal feedback was prepared for the evaluation of the 360-degree video. They contain the following technical statements:

- Previous interest to deal with head mounted displays
- Scepticism towards new technologies
- Gathering information about new technologies
- Acquiring technical knowledge
- Support for operation
- Simple usage of the head-mounted display
- Wearing comfort of the head-mounted display
- Nausea
- Presence
- Comprehensibility content
- Learning success of hotspots
- Content transmission compared to conventional videos
- Appropriate duration of the 360-degree video
- Viewing from 360 degrees
- Good support of conventional training courses
- More frequent use
- Have fun watching

The statements have to be evaluated on a 5-digit Likert Scale (5 - does not apply at all, 4 – rather not applies, 3 - partly, 2 - applies, 1 - totally applies). Compared with other questionnaires the TUI questionnaire treats also the immersion. The questionnaire has to be adapted, because there are some facts which should be evaluated, but were not mentioned in the TUI questionnaire. The adopted questionnaire additionally covers the topics nausea, usage of the interactive head-mounted display and the duration of the video. The complete questionnaire can be found in the appendix of this thesis.

4.3 Results

The results are derived from the answers to the questionnaire. All participants did not show any special reactions during the 360-degree video. In total, eight participants answered all closed questions. One participant left out one statement and another participant did not choose two statements.

Two participants stated that already before the study there was interest in working with head-mounted displays. Three participants had no interest before and the remaining five chose “partly". Figure 21 shows that nobody is sceptical about new technologies.

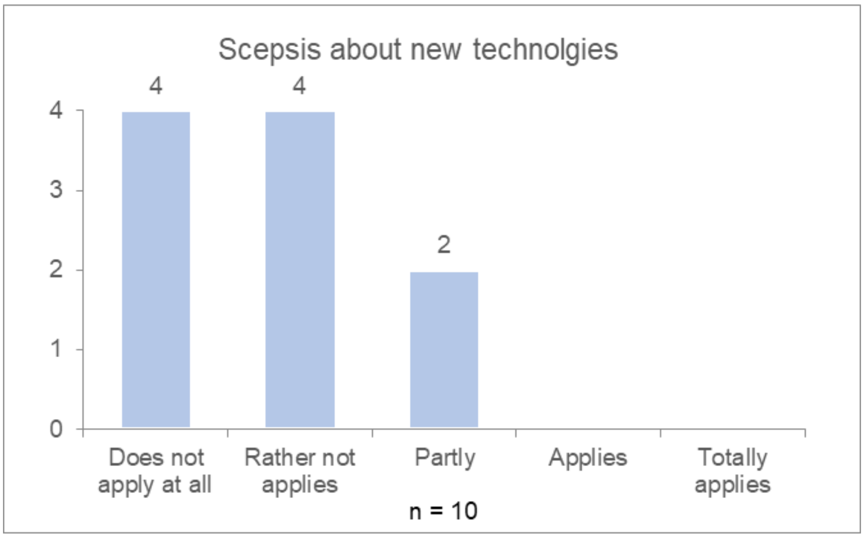

Figure 21: Answer to the statement: “I am sceptical about new technologies.”

50 % of the participants obtain current information about new technologies. Three participants partly obtain information and two participants (n=10) do not inform themselves about new technologies (see Figure 22).

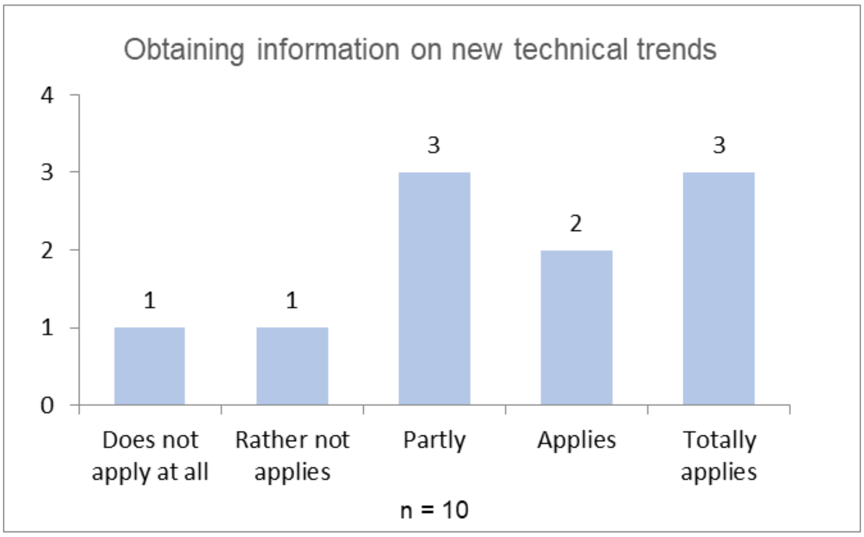

Figure 22: Answer regarding the obtaining of information on new technologies

70 % of the participants have acquired a lot of technical knowledge during their life. For 30 % this is partially the case.

None of the participants would have needed more support for the operation. The majority of the participants (70 %) perceived the interaction with the head-mounted display as easy. For the remaining three participants this was only partially the case (Figure 23).

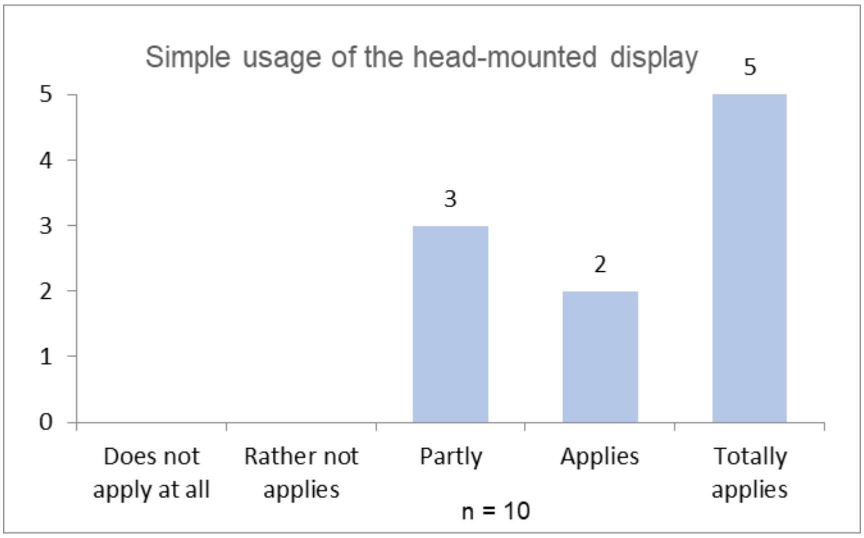

Figure 23: Answer to the statement: “The interaction with the head-mounted display was easy for me.”

If the wearing of the head-mounted display was perceived as uncomfortable, was assessed by 40 % as fully does not apply, 20 % rather not applied and 40 % answered with partly.

In Figure 24 it can be seen, that eight participants had no problem with nausea and one participants suffers nausea.

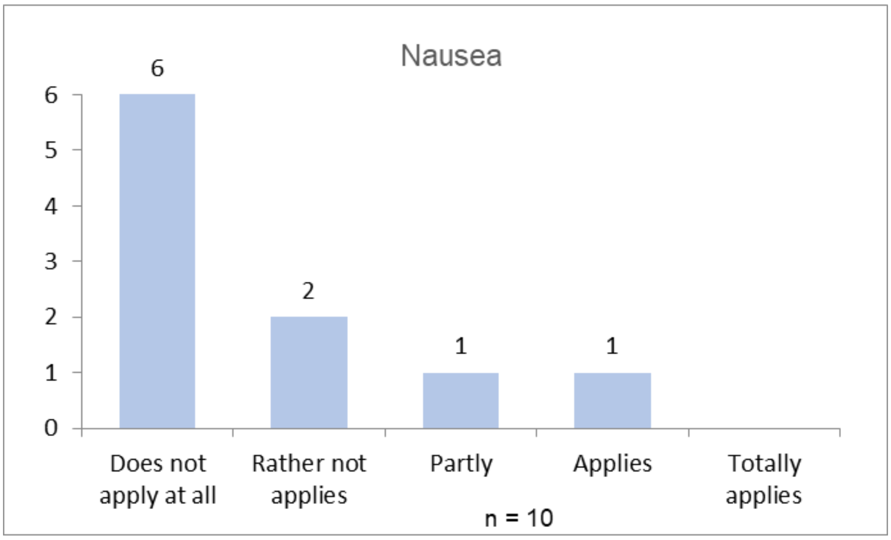

Figure 24: Caused nausea by watching the 360-degree video

Nine participants had the feeling of presence and one participant had partly the feeling of presence. All participants perceived the content understandable and agree that 360-degree videos are a great way to support traditional training.

The use of hotspots was assessed positive: Eight participants (Figure 25) assessed that hotspots increase the learning success. One participant agreed partly to the statement and one participant didn't answer.

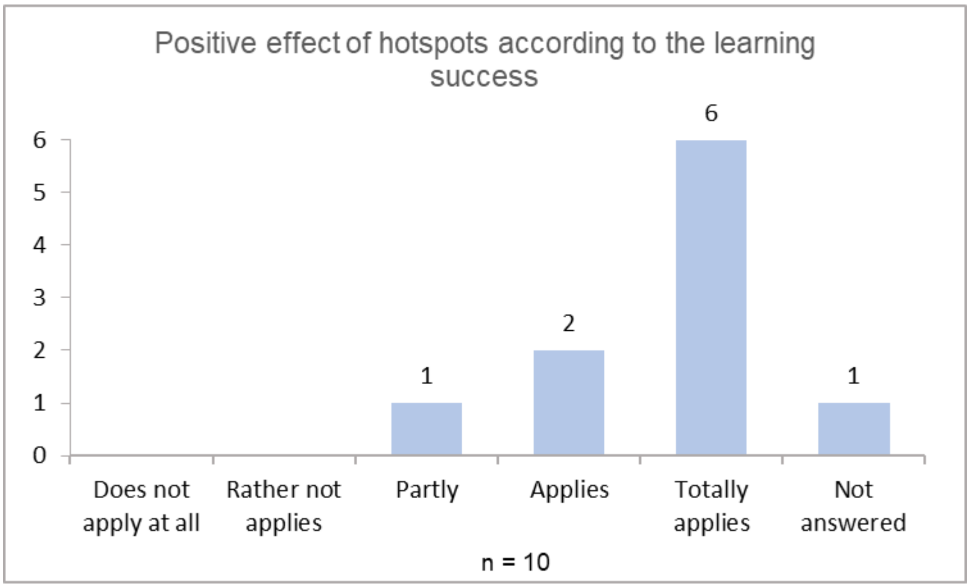

Figure 25: Answer regarding the statement, that hotspots increase the learning success

The statement that 360-degree videos convey the content better than conventional instructional videos was accepted by 80% of the participants (Figure 26).

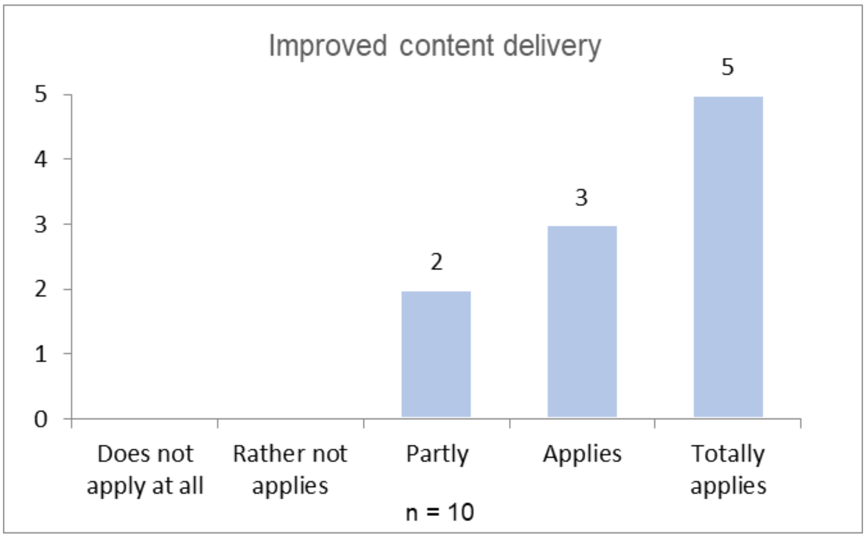

Figure 26: Answer to the statement: “I think 360-degree videos convey the content better than traditional instructional videos.”

None of the participants felt that the 360-degree video was too short, but one participant answers with a partial answer and one participant didn’t answer.

All participants had fun to watch this 360-degree video. 80 % (Figure 27) could imagine using such 360-degree videos more frequently to enhance knowledge.

One participant, who has chosen “partly” noticed that he or she would use 360-degree videos more often if he or she wouldn’t always suffer nausea.

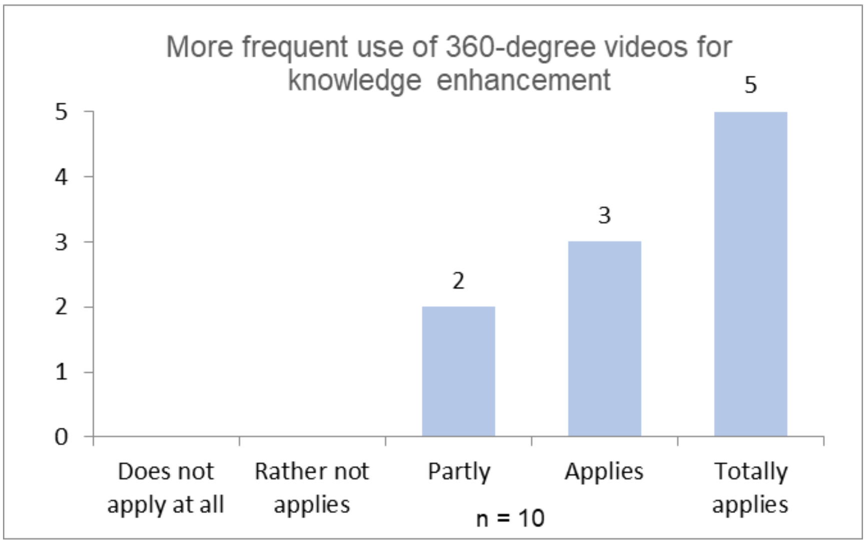

Figure 27: Answers regarding the statement of more frequent use of 360-degree videos to enhance knowledge.

The 360-degree panorama was rated positive by eight participants. One participant evaluated it partially positive and the statement remained unanswered by one participant.

Furthermore, some participants noted in the open feedback question that it is an interesting possibility.

Three participants mentioned personally after the questionnaire that the text in the background was difficult to process

5 Discussion

In general, the 360-degree video was positively evaluated. All participants had fun to watch this 360-degree video and believe that such videos were a good possibility to support traditional trainings. 80% felt that 360-degree videos convey content better than traditional education videos. Furthermore 80% could imagine using such 360-degree videos more often in combination with head-mounted displays.

According to Hebbel-Seeger [8, pp. 266–269] a positive effect of 360-degree video is, that the auditive and the visual perception are addressed. This also makes it possible to present problems and solutions in a real context, as it was done in this 360-degree training video. This context is particularly important for the learning success and depends on the level of immersion. The context is better, the more the learners “immerse" in the situation. The immersive experience can be enhanced by using head-mounted displays.

360-degree videos open new didactic possibilities: Due to the individual selectable image section, the learning environment can be perceived and interpreted based on the own interests, knowledge and experience. In addition, the individual experience and interpretation encourages to talk about the learning situation with others. This exchange also has a positive effect on one's own knowledge construction. The individual selectable image section was also positively evaluated in this pilot study (80%).

No participant had a question in between and most of the participants perceived the use as easy. From this it can be concluded, that no instructor is required when using 360-degree training videos. This is a big advantage, because at the Austrian Red Cross also the training supervisors are mostly volunteering with limited time resources. According to Poxleitner [53, p. 436] it is very important that someone provides answers to open questions. Only in this way the learning process can be positively influenced. For the analysis it would be good if the answers to the questions were stored, so that they could be discussed afterwards. However, it was not of great importance for the evaluation, as only unnecessary pressure would have been generated.

The positive result of this 360-degree training video regarding acceptance, utility, and if some aspects of the evaluation/discussion were included, this can lead to a widespread use of this method in the future.

Limitations/suggestion for improvement for the 360-degree video

One participant suffered nausea during watching and one participant suffers partially nausea. This could be caused by the poor image quality, because according to Richards [54] a good image quality is important to avoid motion sickness. The image quality wasn't decreased during the stitching or the processing in Unity. Accordingly, to increase the image quality another 360-degree camera should be used. An alternative with the Samsung camera could be to use less images per second, which would allow a higher video resolution.

Almost all participants (90%) felt as they were really in the situation, which means that the sense of presence was given. This was achieved through the head-mounted display, where the outside world was totally shielded. Because 40% of the participants felt that wearing the head-mounted display was partly uncomfortable, it would be a possibility to display the video on a mobile device or in a web browser like in the study of Herault et al. [9]. In that case, the place illusion would suffer, but it would open new possibilities. Because the users would be able to experience the 360-degree video with computers and conventional mobile end devices. If the storage would not be local, a high internet rate is required [8, p. 272]. The number of users and the place independency could thus be further increased. Also the big advantage of time-independency of normal videos according to Poxleitner [53] could be ensured with this solution. However, time-independency could also be achieved with head-mounted displays if the ambulance service provides head-mounted displays that are accessible to all paramedics at any time and are compatible with as many mobile phones as possible. So, the learners can watch the 360-degree video, without having a loss of presence, when they have time and do not have to stick to training times. This is particularly advantageous for voluntary paramedics as they are usually exposed to double or triple burdens.

Herault et al [9] mentioned that the use of hotspots is a big advantage over conventional videos. The positive effect of these hotspots was also confirmed in this pilot study. Because of this positive effect, it would have been a good idea to install other hotspots apart from the questions. An example of this would be hotspots, where background information could be looked up. Based on Violante et al. [16] this could be a normal picture, a normal video, a link or documents like word or pdf. For the learning success and according to Bucher et al. [46] it would be a good idea to extend the question hotspots and offer the user more information about the wrong answer.

To make the video more realistic and to increase the interactivity, it would be better if the progress in the scene depends on the answer of the question. Similar to the

360-degree video in Herault et al. [9], where the displayed video (stable or instable patient) depends on the answer.

To increase the learning success even more, a combination of 360-degree video and virtual elements were a good opportunity. Haptic, auditive and visual feedback could be provided. According to Bucher et al. [46] this increases the sense of presence. Another positive aspect is, that “learning by doing” can be integrated, when controllers were used. Also, the difficulties with the usage of head-mounted displays can be solved, because three participants indicated that the operation with the head-mounted display was only partially perceived as easy. Mealy [21, p. 37] mentioned another disadvantage of not using an controller, because the touchpad may not have a natural integration with the virtual world and can pull the user out of the experience.

Limitations/suggestion for improvement for the evaluation

Although not all the participants being interested in new technology, they were open-minded to new technologies. This open attitude is also reflected in the rating, as everyone has rated the 360-degree video quite positively. This openness to new technologies could also be attributed to the relatively young age of the participants. Therefore, it would be a good idea to have the video evaluated by older people as well. But according to Greven et al. [55, p. 179] the older users did not react more sceptically.

Though, the 360-degree video was developed according to the principles of multimedia learning. Three people gave feedback that the sound was difficult to understand or was completely overheard at the beginning. To reduce the cognitive overload, it would be an option to use vision alone. Referring to Slater et Sanchez-Vives [43] it is often enough to use vision alone, because many people are perceptually dominant. Also, the exclusion factor language could therefore be eliminated.

All participants had fun watching the 360-degree video. This can increase the motivation and can therefore increase the learning success. To get more information about the learning success, it would have been a good idea to carry out a video content-related knowledge check before and after the evaluation.

As a next step, comparing the results to a conventional training video could provide an important reference.

6 Conclusion

The evaluation of this 360-degree trainings video and the literature research has illustrated many advantages and some disadvantages.

A disadvantage of 360-degree videos which was determined in this pilot study is that they are not fully interactive. Further negative aspects are the little social interaction and it can be difficult and challenging to don't produce a cognitive overload.

The development effort can vary so much that it is neither positive nor negative. This 360-degree video was the first attempt and took about 70 hours. A similar 360-degree video would now take about 25-30 hours. Despite of the experience, it also depends on the different hotspots, video content and duration.

The following advantages have resulted from this pilot study: repeatability, no supervisor or operator is needed for each training, low costs, navigations and interaction can later be analysed, time-independency, place-independency and several users can train at the same time. The recorded 360-degree view of an authentic scenario leads to a more realistic learning environment. This advantage were also determined in the study of Herault et al. [9] and Bucher et al. [46]. A further positive aspect is that 360-degree videos should have the possibility, that they can be better adjusted to the respective level of knowledge [8, pp. 266–269].

Other advantages which were assessed in this pilot study are interactivity, adaptivity and learner-related feedback. A 360-degree view makes videos completely immersive and the whole range of the camera can be seen. Traditional videos are limited by the pointing of the camera. The results of the study by Violante et al. [16] indicate that 360-degree videos increase the interest, the attention and the concentration and this increases the commitment of the participants.

The current pilot study shows the indication, that 360-degree videos can be a good opportunity to improve or extend the knowledge of paramedics. Conclusions of this evaluation are, that 360-degree videos are a good possibility to train in a realistic and inexpensive way. It promotes self-directed and self-responsible learning. 360-degree videos open new didactic possibilities, because the learner decides where he/she looks at and can see the content from his/her perspective and can immerse himself/herself in what is happening. 360-degree videos won't replace current methods; but they can improve and assist them in a positive way. When developing

360-degree videos, due to the multimedia mode, special attention must be paid to ensuring that the content is based on previous knowledge of the learners and considering the limitation of working memory. Special attention must be paid to exclude nausea as good as possible.

According to this pilot study the following hypothesis can be generated: 360-degree videos are a good opportunity to improve or extend the knowledge of paramedics.

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List of Figures

Appendix

Questionnaire

Melanie Griesser
Studiengang Digital Healthcare

/ gesundheit
/ medien & digitale technologien
fh /// st. pölten

Fragebogen zur Evaluierung
des 360-Grad Schulungsvideo

1.) **Angaben zur Person**

Geschlecht: ☐ weiblich ☐ männlich

Alter: .... Jahre

Seit wann bis du SanitäterIn? .... Jahre

Hast du Erfahrungen mit 360-Grad Videos? Wenn ja, welche?

Hast du schon einmal eine VR-Brille verwendet??

☐ Ja
☐ Nein

2.) **Richtlinien**

Der dir vorliegende Fragebogen umfasst 17 Aussagen. Diese beziehen sich einerseits auf die Benutzerfreundlichkeit, auf das VR-Erlebnis und auf den Inhalt.

Bitte lies die Aussagen sorgfältig durch. Entscheide dann, wie sehr die jeweilige Aussage für dich zutrifft und mache ein Kreuz an der entsprechenden Stelle. Du hast die Möglichkeit fünf Abstufungen zu wählen. Bitte lass keine Antwort aus und antworte spontan. Es gibt keine richtigen oder falschen Antworten.

3.) Fragebogen

	Trifft gar nicht zu	Trifft nicht zu	Teils teils	Trifft zu	Trifft völlig zu
Ich wollte mich schon früher mit VR-Brillen beschäftigen.					
Gegenüber neuen Technologien bin ich skeptisch.					
Ich versuche immer aktuelle Informationen über neue technische Entwicklungen zu bekommen					
Im Laufe meines Lebens habe ich mir viel technisches Wissen angeeignet.					
Ich hätte mehr Unterstützung für die Bedienung benötigt.					
Die Interaktion mit der VR Brille fiel mir leicht.					
Ich habe das Tragen der VR-Brille als unangenehm empfunden.					
Mir wurde schlecht beim Betrachten des 360-Grad Videos					
Ich hatte das Gefühl, die Situation wirklich zu erleben.					
Ich finde, der Inhalt des Videos war verständlich.					
Ich denke, die Verwendung von Hotspots zB Fragen, erhöht den Lernerfolg					
Ich finde, durch 360-Grad Videos wird der Inhalt besser vermittelt als bei herkömmlichen Lehrvideos.					
Ich habe das 360-Grad Video als zu kurz empfunden.					
Ich habe es gut gefunden, die Situation aus unterschiedlichen Perspektiven betrachten zu können.					

Ich finde, 360-Grad Videos sind eine gute Möglichkeit, um herkömmliche Schulungen zu unterstützen					
Ich könnte mir vorstellen, solche 360 Grad Videos in Verbindung mit VR-Brillen öfter zu verwenden, um mein Wissen auf dem aktuellen Stand zu halten/ erweitern.					
Es hat mir Spaß gemacht, dieses 360-Grad Schulungsvideo mit einer VR-Brille anzusehen.					

4.) Persönliches Feedback

Platz für ein kurzes persönliches Feedback deines Eindrucks über dieses 360-Grad Video

Vielen Dank für deine Hilfe!

Declaration of consent of the actors

EINVERSTÄNDNISERKLÄRUNG FOTO- UND VIDEOAUFNAHMEN

Ich ……………………………………………………………………………………
(Name und Vorname, Geburtsdatum)

- ❑ bin einverstanden, dass…
- ❑ bin nicht einverstanden, dass…

Die Videoaufnahmen und Bildaufnahmen im Zuge der Masterarbeit „Interactive 360 degree videos with head-mounted displays in training paramedics“ von Melanie Griesser verwendet und veröffentlicht werden darf.

- ❑ bin einverstanden, dass…
- ❑ bin nicht einverstanden, dass…

Das produzierte Video, zu Promotionen-Zwecken und Schulungszwecken vom Österreichischen Roten Kreuz verwendet werden darf.

Ort, Datum: ………………………………………………

…………………………………………………………
Unterschrift