Comparing spatial, peripheral and emotional perception in a HMD virtual reality with their real world counterparts

Masterarbeit

zur Erlangung des Grades eines Master of Science (M.Sc.)
im Studiengang Wirtschaftsinformatik

vorgelegt von

Andreas Münch

Erstgutachter:	Prof. Dr.-Ing. Stefan Müller (Institut für Computervisualistik, AG Computergraphik)
Zweitgutachter:	Msc. Gerrit Lochmann (Institut für Computervisualistik, AG Computergraphik)

Koblenz, im April 2016

Erklärung

Ich versichere, dass ich die vorliegende Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.

	Ja	Nein
Mit der Einstellung der Arbeit in die Bibliothek bin ich einverstanden.	☐	☐
Der Veröffentlichung dieser Arbeit im Internet stimme ich zu.	☐	☐

....

(Ort, Datum)   (Unterschrift)

Abstract

In recent years head mounted displays (HMD) and their abilities to create virtual realities comparable with the real world moved more into the focus of press coverage and consumers. The reason for this lies in constant improvements in available computing power, miniaturisation of components as well as the constantly shrinking power consumption. These trends originate in the general technical progress driven by advancements made in smartphone sector. This gives more people than ever access to the required components to create these virtual realities. However at the same time there is only limited research which uses the current generation of HMDs especially when comparing the virtual and real world against each other. The approach of this thesis is to look into the process of navigating both real and virtual spaces while using modern hardware and software. One of the key areas are the spatial and peripheral perception without which it would be difficult to navigate a given space. The influence of prior real and virtual experiences on these will be another key aspect. The final area of focus is the influence on the emotional state and how it compares to the real world. To research these influences a experiment using the Oculus Rift DK2 HMD will be held in which subjects will be guided through a real space as well as a virtual model of it. Data will be gather in a quantitative manner by using surveys. Finally, the findings will be discussed based on a statistical evaluation. During these tests the different perception of distances and room size will the compared and how they change based on the current reality. Furthermore, the influence of prior spatial activities both in the real and the virtual world will looked into. Lastly, it will be checked how real these virtual worlds are and if they are sufficiently sophisticated to trigger the same emotional responses as the real world.

In den letzten Jahren rückten Head Mounted Displays (HMD) und ihrer Fähigkeit täuschend echte virtuelle Realitäten zu erstellen immer stärker in den Fokus von Medien und Verbraucher. Hintergründe hierfür sind eine konstanten Steigerungen der Rechenleistung bei gleichzeitiger Verringerung des Strombedarfs und die Miniaturisierung von Bildschirmen. Diese Trends haben ihren Ursprung im allgemeinen technischen Fortschritt und werden besonders von Smartphone Herstellern vorangetrieben. Dadurch sind immer mehr Menschen in der Lage die nötige Hardware zur Erzeugung von virtuellen Realitäten zu beschaffen. Gleichzeitig gibt es nur eine geringe Anzahl an wissenschaftlichen Artikeln, die die Möglichkeiten der aktuellen HMD Generation in Betracht ziehen, insbesondere wenn es sich um Untersuchungen über die Unterschieden und Gemeinsamkeiten von echter und virtueller Realität handelt. Ansatz dieser Arbeit ist es mithilfe von aktueller Hardware und Software die Abläufe bei der Navigation von Räumen zu untersuchen, sowohl im virtuellen als auch realem. Hauptaugenmerk liegt hierbei zum einem auf der räumlichen und peripheren Wahrnehmung, da es ohne ein Gefühl für die Größe eines Raumes nur schwer ist sich in diesem zurechtzufinden. Auch wird der Einfluss von vorherigen realen und virtuellen Aktivitäten darauf untersucht. Weiterhin wird der Einfluss auf die Gefühlslage untersucht, um zu vergleichen inwiefern sie der realen Realität entsprechen. Zur Untersuchung dieser Einflüsse wird eine Beobachtung mit der Oculus Rift DK2 durchgeführt. Hierfür werden Versuchspersonen entweder durch ein reales Gebäude oder sein virtuelles Abbild geführt. Daten werden auf eine quantitative Weise mittels Fragebögen erhoben. Abschließend werden die gefundene Zusammenhänge auf Basis statistischer Auswertungen diskutiert. Bei diesen Experimenten wird die unterschiedliche Wahrnehmung von Distanzen und Räumen untersucht und welche Veränderungen sich in einer virtuellen Realität ergeben. Weiterhin wird geprüft, inwiefern vorherige reale räumliche Aktivitäten die Wahrnehmung in der virtuellen Realität beeinflussen und ob sich eine Einfluss von vorheriger virtueller Erfahrung feststellen lässt. Auch wird geprüft, ob die heutigen virtuellen Realitäten bereits echt genug sind, um die gleichen Gefühlseindrücke wie die reale Realität zu erzeugen.

Contents

List of Figures

Chapter 1

Introduction

This chapter will give an introduction to the thesis. First the motivation and reasoning behind the chosen research field will be highlight, followed by an overview of the historic developments and prior research in each of the fields. Lastly, the research design will be detailed which includes methods used as well as questions to be investigated.

1.1 Motivation

In recent years the topic of virtual reality (VR) gained a new approach of presenting virtual worlds with a wealth of new technology released. They combine a head mounted display (HMD) with head movement tracking and gestural input both in a seated and standing environment with the latter relying on room scale positional tracking. This triggered a surge of media coverage as there is a wide range of possible applications. Of note is that this hardware is aimed at the consumer market with upcoming future availability in retail stores as well.

One of these are video games where a number of games from a variety of genres are under development or partially released. They range from small independent developer working in their spare time to large companies showing ideas for their long running franchises. They offer a new way of interaction between the player and the world especially for first person (FP) games. Examples with a focus on action are Valve's FP puzzle "Aperture VR" Demo based on their successful Portal franchise [1], Unreal Games FP shooter "Bullet Train VR" Demo [2] and Owlchemy Labs FP simulator "Job simulator" [3]. Examples for games with a more calm focus are Three One Zero's FP Space Adventure "Adrift" [4] and Google's paint tool "Tilt brush" [5].

However gaming isn't the only application for this technology. Another field with a noticeable number of innovations is films. This technology enables the presentation of material filmed with multiple cameras to form a 360 degree viewing field that allows viewers to turn around while watching and experiencing the film in a new way. These range from short promotional trailer to music videos to narrative focused pieces. Examples for this include a recent star wars trailer [6], a music video from J-Pop artist Kumi Koda shown in October 2014 [7] and Oculus Studio's "Henry" short film [8]. Furthermore, this year the renown Sundance independent film festival as well as the Tribeca Film Festival had a number of VR experiences shown based on

---

[1] www.youtube.com/watch?v=BWjP77TztTQ, last access 15.04.16

[2] www.youtube.com/watch?v=DmaxmnPzMWE, last access 15.04.16

[3] www.jobsimulatorgame.com, last access 15.04.16

[4] www.youtube.com/watch?v=b98j9w7Pet4, last access 15.04.16

[5] www.youtube.com/watch?v=uFWw6hGIKmc, last access 15.04.16

[6] www.facebook.com/StarWars/videos/1030579940326940/, last access 15.04.16

[7] www.aramajapan.com/news/music/musicvideo/new-koda-kumi-video-to-utilize-360-degree-oc 9123/, last access 15.04.16

[8] www.storystudio.oculus.com/en-us/henry/, last access 15.04.16

new VR focused categories as a sign of the growth in this type of media [9] [10].

Application extend beyond pure entertainment as well. Already some educational material is created to give a better insight in areas previously limited to only one locations. Examples for this include visiting an archaeological excavation site in Ellwangen [11] as well as a NASA backed Mars exploration demo [12]. Moreover, commercial companies traditionally unconnected to technology sector started to develop ways of using this technology to enrich their products. Examples for this include a virtual showroom for Audi cars [13] and IKEA kitchens [14] as well as a virtual roller coaster synchronised with a real one found in the largest German theme park the Europa-Park in Rust [15].

The origin of this can be traced back to the initial Oculus Rift Kickstarter campaign in August 2012, were Palmer Luckey and his newly founded Oculus VR Inc. gather funding for their prototype headset. It was basic, but already included the a majority of the technologies needed. The campaign was a success with enough funds being pledged within 24 hours and receiving almost $2.5 million which is about ten times the initial funding goal [16]. This was followed by the release of the first Development Kit in March 2013, which improved on the initial design and was available to wider group of developers. After a period of further software improvements the social media company Facebook Inc. bought Oculus VR for around $2 Billion in March 2014. Around the same time the Development Kit 2 was announced, which further improves the hardware and reduces issues with motion sickness. It sports a Full HD display with a refresh rate of 75 hz. It was also aimed at a broader audience than the previous one despite it's "Development Kit" label. Under the new ownership Oculus started to engage in a range of collaborations including the technology conglomerate company Samsung. The first consumer version of the Rift was announced in May 2015 and started shipping in late March 2016. It improved overall build quality, increased the display resolution to 2160*1200 pixel and it's refresh rate to 90 hz to further reduce problems related to motion sickness and improve the overall experience while using it. Reviews were very positive citing the good design and great experiences while using the headset. Main critic point was the rather high prices at around 600 $ and the current lack of content, both of which are not uncommon for new technology. [17] [18].

Apart from Oculus and Samsung other large technology companies started to build their own virtual reality headset as well. A direct competitor is HTC's Vive headset created in collaboration with video game developer Valve. It was announced in March 2015 during the Mobile World Congress with limited availability of a development headset starting in September 2015 and the first consumer version shipping in April 2016 [19]. While the headset itself contains similar hardware as the Rift, it contrasts by being designed for use while standing and features positional tracking in a 5*4m meter room. This results in a higher price, but also in a better ex-

---

[9] www.sundance.org/blogs/news/new-frontier-projects-and-films-announced-for-2016-festiv last access 15.04.16

[10] www.fortune.com/2016/04/16/virtual-reality-movies-tribeca, last access 19.04.16

[11] www.youtube.com/watch?v=LYbOf60eiMI, last access 15.04.16

[12] www.unrealengine.com/showcase/nasa-is-using-unreal-engine-4-to-make-mars-a-virtual-r last access 15.04.16

[13] www.youtube.com/watch?v=fvQS8ImnSsw, last access 15.04.16

[14] www.ikea.com/us/en/about_ikea/newsitem/040516_Virtual-Reality, last access 15.04.16

[15] www.europapark.de/en/park/attractions-shows/alpenexpress-coastiality, last access 15.04.16

[16] www.kickstarter.com/projects/1523379957/oculus-rift-step-into-the-game, last access 15.04.16

[17] www.techradar.com/reviews/gaming/gaming-accessories/oculus-rift-1123963/review, last access 15.04.16

[18] www.theverge.com/2016/3/28/11284590/oculus-rift-vr-review, last access 15.04.16

[19] http://blog.htcvive.com/us/category/vive-news-events/, last access 15.04.16

perience according to recent reviews [20] [21]. Another major competitor was announced in March 2014 with Sony's Playstation VR and has an estimate shipping date of October 2016 [22] [23]. In contrast to the previous two headsets it doesn't run software on a computer, but rather on Sony's Playstation 4. While the Display resolution is lower with 1920*1080, the refresh rate is technically higher at 120 hz, although the console renders only at 60 frames per second.

Besides these stationary HMDs there are also a number of mobile ones that can be used independent of the location or availability of computing power. The two most notable ones in this area are Samsung's Gear VR, which was created in cooperation with Oculus VR, and Google's Cardboard. Both of these are self contained as they use smartphones for rendering the software and tracking the head movement of the player. The Gear VR is more sophisticated and works only with a selected number of Samsung high end smartphones. These often have an higher resolution display than the stationary headset, but don't reach the high refresh rates and are limited by their mobile CPUs and GPUs as well as battery capacity. The cardboard is an interesting approach as it is actually made out of cardboard and offered at very low price. It is also compatible with a wide range of Android and iOS based smartphones, although not all of them can deliver a good experience.

Figure 1.1 shows pictures of the discussed headsets. Besides the headset (C) also shows the gestural input methods as well as the base stations needed for positional tracking used by the HTC Vive. While there was not an unified input method during the DK 2 (A) times, Rift Consumer Version (B) ship with a Microsoft Xbox One gamepad.

Albeit different in shape they all work based on two slightly different perspectives and a set of special lenses that shift the focal point further into the distance to create the illusion that the display is further away. This makes it necessary to have the same basic components in all headset. Over the past years display technology made constant progress towards more compact and higher resolution displays. These display tend to be compact in size with high resolutions and options for high refresh rates. Being able solely rely on using a smartphone also shows that there is already enough basic computing power available.

(a) Oculus Rift Dev Kit 2 © wikipedia.com   **(b)** Oculus Rift Consumer Version © oculusVR.com   **(c)** HTC Vive Consumer Version © htcvive.com

---

[20] http://arstechnica.co.uk/gaming/2016/04/htc-vive-vr-headset-review, last access 15.04.16

[21] www.theverge.com/2016/4/5/11358618/htc-vive-vr-review, last access 15.04.16

[22] http://blog.us.playstation.com/2014/03/18/introducing-project-morpheus/, last access 15.04.16

[23] http://blog.us.playstation.com/2016/03/15/playstation-vr-launching-october-for-399/, last access 15.04.16

(d) Sony Playstation VR © blog.playstion.com   **(e)** Samsung Gear VR © samsung.com   **(f)** Google Cardboard © google.com

Figure 1.1: A selection of notable headsets

History of virtual reality HMDs This high interest in virtual reality is not exclusive to the 21. century. Even before the term was coined in 1987 by Researcher Jaron Lanier there were a number of attempt to create a virtual reality, with analogue as well as digital images [24].

The first HMD display was proposed by Ivan Sutherland in 1965 [1] and subsequently build in 1968 [2] named "Sword of Damocles". He aimed to create a three dimensional display to give the wearer additional information. He approach this project by using two miniature CRT displays combined with mechanical and ultrasonic head position tracking. It was so heavy that it needed to be suspended from the ceiling (hence the name). Albeit primitive it worked well with the computing power limitations of this period time by relying on basic wireframe shapes. However, this technology was largely constraint to research, both civilian as well as military, without the general media covering it much.

After decades of being limited to research projects public interest started to increase in the early 80s. Around this time the first home computer and gaming consoles were released and the general available computing power and display technology have improved. First films where made with computer generated special effects such as "Tron" from 1982. Also a number of fiction writer started covering this topic as inspired by the new possibilities to create virtual worlds connected over the internet. A notable example for this is William Gibson's novel "Neuromancer" from 1984. Over the next decade a number of films, TV series and novels explored these combination of topic which where covered in the general media as well. Also a number of arcades were built to give people first impressions of virtual reality. This interest cumulated in the development of the SEGA VR Headset for it's Genesis console in 1993 and the release of Nintendo's "Virtual Boy" in 1995 as shown together with the "Sword of Damocles" in figure 1.2. Both of them were aimed at a broader audience to be used with readily available computers. While the former was intended to be portable, the latter required a tripod. However, their graphical fidelity was much behind what people anticipated with the virtual boy only rendering images in red and black and lacking proper software support. At this point the general public became aware of the virtual reality hype and how it was limited by the current computing power and low spec displays. [25] [26]

---

[24]www.vrs.org.uk/virtual-reality/who-coined-the-term.html, last access 15.04.16
[25]www.vrs.org.uk/virtual-reality/history.html, last access 15.04.16
[26]www.theverge.com/a/virtual-reality, last access 15.04.16
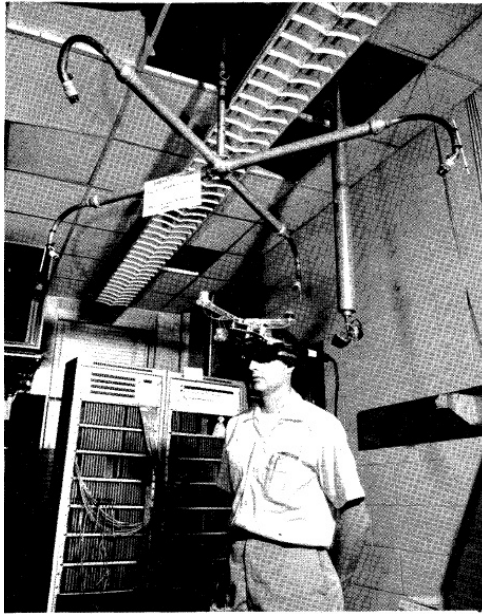
(a) First HMD by I.Sutherland

(b) Nintendo Virtual Boy © wikipedia.com

(c) Sega VR Headset Concept © vrs.org.uk

Figure 1.2: A selection of notable old headsets from 1968 till 1995

Focus of this thesis Based on the wide range of applications there are also plenty of possibilities for research. As all of the headsets and software are aimed at the broader audience doing a study with humans and how they perceive virtual realities created by these has the promise of uncovering useful insights. Furthermore, it would be wasted potential to not use current technologies to research in conditions similar to the ones currently available on the market. However, searching for all influences at the same time might prove too time consuming and highly complex. Looking again at the headsets it becomes apparent that all of them rely heavily on displays and lenses to change the visual perception of the user and create virtual worlds more alike to the real one. Examining how well this works would be therefore an interesting focus.

Choosing a specific areas proves again challenging as all of them promise to be worthwhile. One of them is navigation of virtual space, which is a common and necessary task in the virtual world, both in gaming and non-gaming. Because of it's ubiquity this a very interesting field. A requirement for navigation is the perception of the space around oneself. This includes its structures and their dimensions as well as the objects and how they are related. Perception of these is also governed by the expectations and experiences someone had in the past. Navigation is often a task were past knowledge and assumptions play an important role. Seeing how these are affected and their potential to contribute in the virtual world is another worthwhile task. Finally, the HMD enclose the whole field of view with no connection back to the real reality. As mentioned in a previous example this makes it possible to visit or experience otherwise rare events or places. These circumstance certainly have an influence on the emotional state of the wearer as the illusion is his/her only reference and visual perception plays a major role for

this in the real world.

1.2 Prior research

Apart from the historic research the general understanding of what constitutes VR hasn't changed much since the late 80s. Even the definition of Lanier in a panel session for SIGGRAPH 1989 holds up today [3]. In it he describes VR as an virtual simulation of reality surrounding a person that is perceived in a similar way to the real world. His mentions of the equipment also have common features to the modern headsets as he draws attention to the display showing stereo pictures to create a three dimensional impression as well as head tracking which is correctly translated into the virtual space. Further notable researchers since then include Myron Krueger [4], Scott Fisher [5] and Mark Bolas [6].

Preliminary literature analysis showed a lack of specific research into virtual reality under the selected scopes. To get a better picture this search was done again while including a broader understanding of virtual worlds not limited to HMDs.

Spatial Perception in virtuality has been explored in the past in a few contexts. For example Bülthoff et. al. [7] looked into the perception and recognition of the spatial layout by using a VR simulation and testing the impact on the perception of object movement. In contrast Interrate et. al. [8] looked into the influence different sized virtual environments have on the spatial perception. Moreover, Roca-Gonzalez and Martinguez [9] looked into how the spatial perception can be improved by using a virtual environment. A more broad approach was taken by Henry [10] who looked into spatial perception and how it can be used in an architectural application. Another interesting experiment was done by Richardson et. al. [11] who looked into how the acquisition of spatial knowledge was influenced by using a virtual world.

Peripheral perception has been looked into only in a very limited manner. The only notable example is Fortenbaugh et. al. [12] who researched the effect of peripheral perception on navigational abilities by experimenting in a virtual forest.

The influence of virtual places on emotions is a highly researched topic in recent years with a variety of applications in therapy of anxiety disorders. Two review of research on this topic from Diemer et.al. [13] as well as Opris et. al. [14] give an overview. They both find a number of research which were enabled by VRs ability to generate complex situations in a controlled manner. While the former aims to summarize the current research, the latter aims at comparing the virtual therapy approach with classical real one. Examples for applications are Hodges et.al. [15] who used it to explore possible treatments for fear of heights, Alsina-Jurnet et. al. [16] who looked into the effect of different virtual environments on examination anxiety and Ling et.al. [17] where they looked into the influence on public speaking anxiety.

Finding literature about the change in spatial perception based on prior experiences proved to be very difficult. As there was already only limited prior work found for the baseline spatial perception there weren't any articles found on this specific topic. Most of the times the focus lies more on the influence on the narrative of a virtual world.

1.3 Research Design

Defining a set of core follows largely follows the observations stated in the previous sections with the core idea being how a HMD based virtual reality influences humans. Based on the fields selected as worth researching these are as following:

1. How is the spatial perception influenced?

2. How is the peripheral perception influenced?

3. What influence has prior experience?

4. How does the emotional response change?

To gather data towards these questions it is necessary to first choose a research method. While literature can be found on most of the topics, it often lacks in regard of the use of modern hardware. Most of them used older models or different approaches , which were almost excursively used in research either because of extensive cost or space requirements. The reason for this mostly likely lies in the rapid pace of innovation in this area, as it's only three years ago that the first modern headset was released. Furthermore, because one of the goals is to look into the influence on humans, a qualitative approach promises more insight. As data is scarce it needs to be gather before any research can be conducted. Among the available methods an survey based experiment is most suited for to generate and gather this data. As this is a test between HMD based virtual and real world the test needs to be held at least twice. However, because a virtual model is never completely accurate there is the need for a third test series to make sure that the differences are based on different perception and not on different representation. The environment used should be somewhat similar to the HMD one. Because HMD are at their core high resolution displays a high resolution TV seems to be a suitable choice. It shares input options with a headset, while also have been used by most people before. To get a good overview the sample size shouldn't be too low. Equally it can't be too high as experiments in general tend to be time consuming to conduct and prepare. To strike a balance between those two the goal is to have at least 20 subjects in every test section. To make sure that the data is comparable the experiment needs to be held at a location which is available in all three environments. Finding this location is limited by the selection of available virtual models. Coincidently the research group developed a detailed model of the local fortress Ehrenbreitstein several years ago. This is a very good location as the wide area offers a large number of possibilities to gather data.

Now the research questions (RQ) can be broken down into hypothesises which in turn will serve as guidelines for the survey. For the first RQ this means finding some key activities of spatial perception. As mentioned one of them is the perception of dimensions of objects and how they relate to oneself. This is often done in the real world and involves estimation as the true values are rarely known. Besides the estimation of dimensions of objects another common task is to estimate distance from the current location to a different one. Both of these play a valuable role in orienting in a larger space. Moreover, an equally important navigation task is to relate certain landmarks of specific dimensions to the current location. Besides the distance between those two points it's orientation is also equally important. This leads to four different hypothesises which are as follows:

1. RQ 1a The error in estimating is significantly different when judging distances

2. RQ 1b The error in estimating is significantly different when judging the size of a room/area

3. RQ 1c The error in estimating is significantly different when judging the walked distance

4. RQ 1d The error in estimating is significantly different when judging the angular position of points

While the second RQ focusing on peripheral perception involves a less complex task, it's nevertheless important for navigating a space, be it real or virtual. This type of perception is often unintended as it's based on the peripheral vision. As this is also influenced by the size of the object and when it was encountered it would be interesting to separate this questions in two. One for smaller objects recently encountered and another one for larger objects encountered longer ago, while still staying inside the time constraints of the experiment.

1. RQ 2a Peripheral perception is significantly different when asked about smaller objects recently encountered

2. RQ 2b Peripheral perception is significantly different when asked to locate larger objects encountered longer ago

The third RQ is based on the previous two in regards to the perception, but it differs from them by including prior experiences. As the experiments are conducted in the real and virtual world these hypothesises needed to differentiate between those two. This make the formulation quite straight forward. However, finding a set of survey questions reflecting these experiences will be more difficult as there is a wide range of experience to ask for.

1. RQ 3a Prior real experiences significantly influences 2D distance judging

2. RQ 3b Prior real experiences significantly influences 3D Space judging

3. RQ 3c Prior real experiences significantly influences peripheral perception

4. RQ 3d Prior gaming experiences significantly influences 2D distance judging

5. RQ 3e Prior gaming experiences significantly influences 3D Space judging

6. RQ 3f Prior gaming experiences significantly influences peripheral perception

The topic of the final RQ in regards to emotional perception can be covered extensively. Also as this involves the highly complex human mind which is researched in the fields of psychology there is not a definite answer. It rather is collection of different believes and assumption, which changed over the last decades. Nevertheless, this needs to be simplified to fit inside the scope of this research. This leads to the assumption that there is an undetermined number of emotions positively or negatively affecting humans which can be influenced by the visual perception.

1. RQ 4a The perception of positive emotions is significantly different in different realities

2. RQ 4b The perception of negative emotions is significantly different in different realities

Chapter 2

Technical Implementation

This chapter describes the implementation effort done to convert the old fortress model to a modern HMD capable one. After a description of the initial basic model and it's shortcomings, a comparison between a selection of modern game engines is made to determine the most suitable one. Finally, the process and challenges of converting the initial model to an improved HMD capable one is detailed.

2.1   Description of initial model

The model was originally created during the "Eduventure II" project [1] as a collaboration of the local departments for "computational visualistics" and "knowledge media" supported by the State Museum Koblenz and the "Landesamt für Vermessung und Geobasisinformationen Rheinland-Pfalz". The project started in March 2006 and was unexpectedly shutdown in June 2007, due to lack of funding. The goal of the project was to create a serious videogame to teach about the history of the fortress and the Prussians who held it during the 19. Century. Because of this, the model was aimed to represent the status of the fortress around 1848. The model itself was created with Autodesk's 3d Studio Max 5.1 (2002) while the game was based on Bethesda's "Oblivion" (2006) which uses Gamebase USA's Gamebryo engine. The model saw it next use around 2011 when it was ported over to Blender Foundation's Blender 2.57 and subsequently used with Unity Technologies Unity engine, presumably Version 3, to tour the fortress grounds by members of the department. Some years later around Summer 2015 it was again upgraded to a more modern version this time Unity 4 to enhance the tour with some basic HMD and head tracking support. A selection of screenshots from this model can be found in figure 2.1.

After an examination of the model regarding visual fidelity there were several shortcomings found. The first problem was the low visual fidelity as seen in the screenshots, which is caused by used engine and can't be fixed sufficiently by tuning available settings. While this might be acceptable when only examining the spatial perception, Diemer et. al. [13] found a positive link between an increased presence and the a better convening of emotional responses. To improve presence Averbukh [18] suggests to increase the visual fidelity. To achieve this a newer engine with a selection of modern render techniques is needed.
The next problem was the requirements of the hardware. While the TV had a high amount of pixels (around 8 Million at 60 frames per second(fps)), the HMD had a rather high perquisites regarding the frame rate (2 Million Pixels at 75 fps), which should be met at all times to prevent negative side effects such as motion sickness. This requires an efficient engine to handle the rendering. As the Unity 4 Engine was initially release in Nov 2012 an upgrade to a newer game engine would certainly help tackling this.
Finally, the Unity 4 engine doesn't have native support for HMDs and head tracking. The previous project had to use a set of plug-ins to enable basic support for these features. However,

---

[1] `www.eduventure.de/viskom_index.php`, last access 13.04.16

9

performances of this method is lower as seen in the following video [2]. This again calls for a more modern engine with native support to further increase the efficiency of the render task.

(a) Old version of courtyard   **(b)** Old version of Rheinbastion   **(c)** Old version of area over tunnel

(d) Old version of tunnel   **(e)** Old version of Osthof

Figure 2.1: Screenshots of the old model based on unity 4

2.2 Comparison of game engines

Finding game engines which met the specified criteria was not complex as there are a number of available candidates with some of them begin free of charge and others requiring a paid licence. As there are were no funds available only the former type was taken into further consideration. As for hardware to work with the lab coincidently procured new computes with powerful components. After some research two promising possibilities were found: the updated Unity Version 5.1 and Epic Games Unreal Engine Version 4.8. Of note is that there were some major changes introduced with Unity 5 which commonly leads to problems with the import of old assets. Both of these engines offer a wide variety of modern rendering approaches and native HMD Support with Unreal focusing more on photorealism on powerful hardware and Unity more on user friendlinesses, accessibility and high efficiency over a range of hardware. After some preliminary familiarisation the blender model was loaded into both of them. While it holds true, that the unreal engine had a higher fidelity than Unity 5, the latter was still well above the Unity 4 version. Nonetheless, as mentioned before the handling of Unity 5 was easier especially for an user new to game development. This became apparent when problems during the import procedure from blender to Unreal started to occur. While eventually these problems could be fixed, it was very time consuming. Nevertheless, as photorealism wasn't the goal and time constraints didn't allowed for lengthy or complex workflows Unity 5 was picked as the future game engine of this project.

2.3 Upgrading the model

Figure 2.2 shows the state of the model shortly after the import in the new environment. During the import a substantial number of assets weren't assigned correctly which forced them to

---

[2]www.youtube.com/watch?v=Nk9QRFds8nE,last access 13.04.16

use the default white texture. However, the import of the level geometry was successful and so the model was technically complete. This is due to the previously mentioned major changes between version 4 and 5. Implementation of the model happened under Windows 7 with Unity Version 5.1.2f.
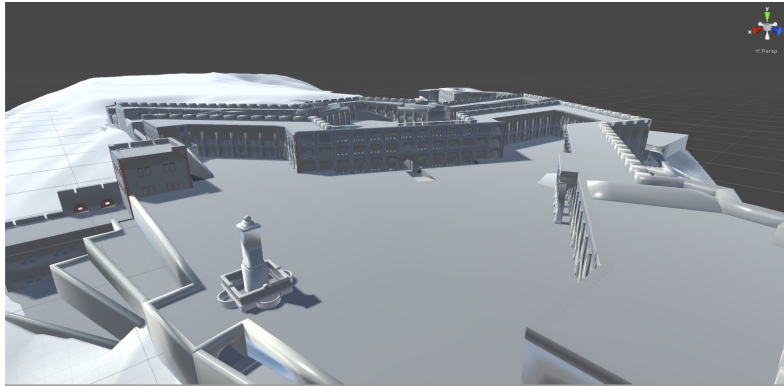
Figure 2.2: The initial state of the model, newly imported into Unity 5

The first steps were made to match the old version and the real fortress so that subsequent steps could focus on improvements needed for this experiment. Over the course of this a number of trips were made to the real fortress where large areas had been remodelled for the "Bundesgartenschau" 2011 to better resemble the historic fortress. During these trips details of this "new" fortress where recorded to serve as a baseline for the new model. While the assignment of textures to geometry has failed, the old assets (textures, normalmaps, heightmaps) were still available hidden inside the folder structure of the old model. Reassigning them was still possible, albeit time consuming as they needed to be compared to the old model first. After this they were improved to match the real fortress more, which included swapping out a number of them such as the one for the courtyard ground. Moreover, some areas had problems with collision detection. These were searched out and also fixed. Besides this a number of features were added. This included multiple types of trees as well as grass and new meshes and objects to fill gaps in the old level geometry. The main improvement was related to lighting as the lack of proper global illumination was a major shortcoming in the old model. This is most noticeable when looking at shadow casting, which was absent in the old model. This was fixed with the help of some extensive and time consuming rendering which took multiple attempts to set up a realistic lighting in all places. The tunnel was a particular problem area as it was mainly lit by indirect lighting in the real world. This required to redo the lighting multiple times and going into the details of unity's lighting backend. Furthermore, there was proper support for HDR and tonemapping Shader added.

Besides the graphical improvements scripts for player interaction were added as well. Unity 5 has native support for two programming languages: C# and Unityscript, which is based on Javascript. Because of prior experiences with the similar language Java and the general preference of the unity developer community to write scripts in C# the former was chosen as the base for any script. While there were some scripts like a basic first person controller already available, they needed to be adapted to work in this model. Other scripts such as the pause menu needed to be created from scratch. This proofed to be somewhat difficult as Unity 5 was just released a few months prior in March 2015 with some documentation not being updated yet. The major changes from Version 4 to version 5 also led to common approaches of solving certain problems like this not being feasible any more.

2.4 Improvements for the experiment

The first step here was to add everything necessary for the TV tests first and then derive a version for the HMD. This led to the addition of more custom scripts especially to gather the necessary data. One such script is used to measure the angular deviation to the well from the current orientation of the player called "Angle Measure". It was based on an script from the previous version, with improvements to the way values are calculated and how the data is written into the results text file.

Another major addition was a guide character, which was needed to match the virtual tests as close as possible to the real one. Just as in these the test participants needed a guide to show them the desired path to the locations of the stops. After considering a variety of options such adding a multiplayer mode for the conductor to join the subject, it was determined that an AI controlled character was the best solution. He acts based on a custom script which uses keyboard presses to change his destination, while his appearance and animations are based on the standard "Ethan" Character model preloaded in unity. Some challenges with implementing him were getting the same path to the locations every time as well as animating him to reflect his current state of motion.

There were two options for controlling the player character: Keyboard and Mouse or a gamepad similar to the ones used by gaming consoles. It's important to note that the chosen input device would be used in both virtual tests. While this wasn't a problem for the TV test, it was important to make the correct decision for the HMD tests where the participants won't be able to see objects in the real world. Another criteria for the HMD test was good support for a standing experience. Because of this the gamepad was found to be more suitable for the experiment as it would allow easier controlling of the player character, due to it's reduced number of buttons. Also it was usable while standing especially because a wireless one was available. Additionally, this allowed to have the participant use a different input device than the conductor which in turn made it easier to control certain elements of the experiment such as the AI guide. Implementation of this wasn't as straightforward as hoped as this was an example of an old script which didn't support the new unity version yet. After some research into unity's input manager the gamepad could be integrated for both basic player locomotion and triggering the Angle Measure script.

Over the course of preparation work a major problem with the model was found. Pre tests showed that participants had problems with the scale of the model which resulted in a wide range of answers. While controlling the model and it's objects, it was also found that there was no unified scale to match the real counterparts. This resulted in a given distance value corresponding to a different size depending on which location the player was currently in. As fixing this problem on a geometry basis in blender, which in turn would lead again to conflicts with the assignment of assets on reimport into unity, would've be very time consuming an alternate solution was needed. A more efficient solution was to create reference structures with a defined length/width of 1 meter. These were placed near the stops to serve as a visual scale cue. The locations themself were marked with white platforms which also had a standard size of 3*3 meters with the exception of the tunnel. The reason for having multiple locations to test at will be discussed in section 3.1. Now the virtual objects could be measured and a set of virtual size values was created. After these problems were solved the TV Version for the experiment could be built.

HMD challenges Deriving a HMD Version from TV Version posed a bigger challenge than initially anticipated. To support development a number of scripts were downloaded from Oculus Website which were intended for Unity 5. This Oculus SDK had the Version number 0.6 and was extended by the Unity integration package version 0.1. Interesting to note is that it was not possible to develop with this versions under the most recent Windows 10 as it had problems with false sensor input. Upgrading to more recent versions only led to problems with the windows version used during development. While the number of scripts and functions

was sufficient, it's structure and how they're connected was not immediately apparent and the documentation for the used version was only superficial. This led to further delay while implementing the model.

Most of the scripts were still usable in the HMD version. Problems occurred with the pause menu as it's approach of drawing buttons on the GUI was not supported by the Oculus Player Controller. Instead a similar script was created with a more basic set of functions. Furthermore, the basic unity cross hair wasn't feasible in this version. While it's sufficient for the TV Version to have a flat one floating a fixed distance in front of the player, this created discomfort in the HMD Version. The problem here was less of a technical nature, but more of a visual nature and based on how the human eyes which always try to adjust focus. With a static cross hair the eyes involuntarily try to focus on it as well as the underlying object, which appeared to be further away. Once the underlying issue was determined a solution was quite straight forward as it simply required the cross hair to take the players orientation and distance to the object he's pointing at into account and adapting it's size accordingly. Another example for this sort of visual problem occurred in combination with the cobblestone ground. When looking down on the texture it appeared to be closer than expected. Initially this was thought to be a problem with the view frustum and that it could be solved by changing the field of view. However, it turn out that this impression was created because the stones displayed on the texture appeared too big for what one would usually expect from a real world cobblestone path. This confused pre testers into thinking the ground was closer than it should be. The solution for this was again rather simple and only required to swap the texture out in favour of one with smaller cobblestones segments. These kind of challenges are unique to the HMD environment as they require to keep the expectations of people based on their real world experiences in mind.

After these problems were fixed and the changes were transferred back to the TV Version telling unity to build a HMD targeted version was rather easy and only required toggling a checkbox in the player settings. The results can be view in figure 2.3, which show the same views in figure 2.1.

(a) New version of Courtyard

(b) New version of Rheinbastion

(c) New version of Area over Tunnel
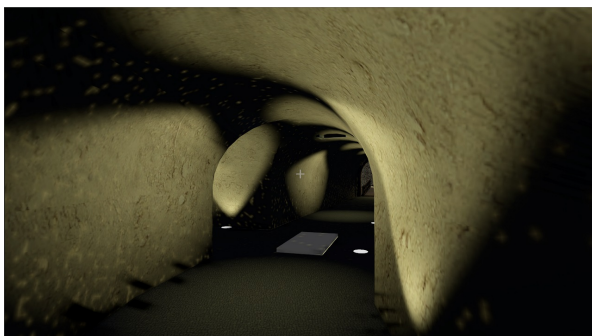
(d) New version of Tunnel

(e) New version of Osthof with AI Guide and reference structure

(f) Overview of new version

Figure 2.3: Screenshots of the new model based on Unity 5

Possible improvements   Due to lack of time and experience in game development for HMDs some features couldn't be implemented. One of them is an additional improvements to lighting as the shadows in the tunnel and from bigger objects are still not quite right. Moreover, it would certainly be an improvement if the player character had visible and fully animated legs especially in the HMD Version. This would enhance the illusion and might lead to better results in areas that rely on a constant feeling of presence such as the emotional questions. Also interesting to explore is the possibility to replace the gamepad in favour of tracking the position of participants in the room and translating his real world movements appropriately into the virtual one. However, this would require additional hardware as it's found in the HTC Vive mentioned in section 1.1. Finally, the AI guide could be improved as well. Guiding him along the correct path during every test was difficult and sometimes random. Also his animations and collision detection showed to be sub par. While the idea of using a computer controlled guide is certainly better than alternatives like being controlled by a human, setting everything up correctly proofed to be time consuming.

Comparison with the real fortress   Comparing the model with the real fortress reveals certain problematic areas even after extensively fixing the mentioned problems. For example is scale still a problem most notably with the well on the courtyard (a in fig. 2.3), which appears too big, and the tunnel and Rheinbastion ((b) in fig. 2.3) area, which appear too small. Rectifying the issues would require to replace these areas in blender with correctly scaled one. The main problem for this is getting the correct data from the corresponding administration office. Texture quality itself was good, but could be improved further to reflect the changes made in 2011. Also while the level geometry for the test area was very good, there are some other spots which had problems with collision detection. Nevertheless, all of these are of no concern for the experiment as the participants will only take part in one test and the model itself is consistent enough to avoid much confusion in regards to scale. In general can be said that the model aged well and was a good basis for implementation.

Chapter 3

Experiment

This chapter focuses on the conduction of the experiment in both realities. First the structure of the experiments will be shown, which serves as the basis for the survey. The next section will detail the separated experiment runs and raise some notable details about them. The last section will present the statistical data analysis where the findings are described.

3.1   Structure of Experiments

Settling on a structure of the experiment was a three step process. First, a structure for the survey was defined. Then a route through the fortress had to be found that allowed to test all the intended features in both realities. Finally, the structure was filled with questions as described in the next section.

To maintain comparability between the different versions of the experiment surveys needed to be as identical as possible, even tough this would mean to included questions not needed for a certain experiment. Also to increase the potential number of participants the survey was designed to work in German and English.

Looking at the hypothesises, there is a difference between those related to research question (RQ) 3 and RQ 1 2. While the former are area independent focused on gathering past knowledge, the latter are area dependent and gather data based on the current situation. RQ 4 is somewhere between those because data can be gather at any location on the fortress, but needs to be generated first by participants seeing the fortress. Because RQ 3 can be addressed at any point it was put in front as the first section, split into one for prior Real and one for prior Virtual. After this RQ 1 respective 2 based hypothesises can be looked into by focusing on the surrounding area of the experiment. Nevertheless, some of these hypothesis are better suited to be tested at the end of the experiment as they focus on the whole areal. This particularly affects RQ 1c and 2b, which made it necessary to add a section to summaries the test at the end. This was also a convenient place to ask about the demographic data of participants. As mentioned RQ 4 needs to be somewhere in the middle of the tests so that participants already have an opinion of the test. This led to related questions being put in the middle of RQ 1 and 2 testing.

The section for spatial and peripheral perception couldn't all the tested at the same area in the fortress as accuracy tends to increase if a person gets familiar with the surroundings [19]. Furthermore, the emotional perception questions also benefit from going around which gives the participants an overview of the fortress area. This made it necessary to determine a route with several stops which had a different set of features to pose questions about, while also keeping the walking distance low. As the area of the fortress is rather large this proofed to be a challenge due to the high number of possibilities. Also spatial proximity of location was an additional factor that needed to be accounted for. Another one was the idea of barriers based on Newcombe et. al [20] and Kosslyn et. al. [21]. They both showed that having an opaque barrier that blocks directly line of sight, like a brick wall, distorts the spatial relations in adults. Nevertheless, they only tested this in the real world and not the virtual one. Testing this would

mean little overhead and could provide some further insight into the differences and similarities between the two realities. It also suits the hypothesis RQ 1d very well as it is focused on the pointing towards a fixed object which is bound to be obscured by walls over the course of the experiment.

The courtyard was chosen as starting area based on it being near an entrance and having a large set of features to focus on. From there the "Rheinbastion" was the only option as a second stop. Form there four possibilities were available of which two led to a dead end, which would've ended the test to early. The other two were going trough the tunnel or above it. To keep the experiment short a stop inside the tunnel was chosen next. This was also a good change from the more open areas before and provided a good barrier point as this area was surrounded by walls in most directions. After this the area along the main road called "Osthof" was chosen as it had more features than the area past the side tunnel and was generally better maintained. Because of the number of walls it also served as a somewhat closed area especially when putting the stop in front of one. However, this path proved to be too short to ask a sufficient number of questions. Because of this the stop above the tunnel was added before going inside the tunnel. This stop also proved to be a good time to ask the participants about their emotional perception. The describe route is displayed in Figure 3.1 which also points out key areas.
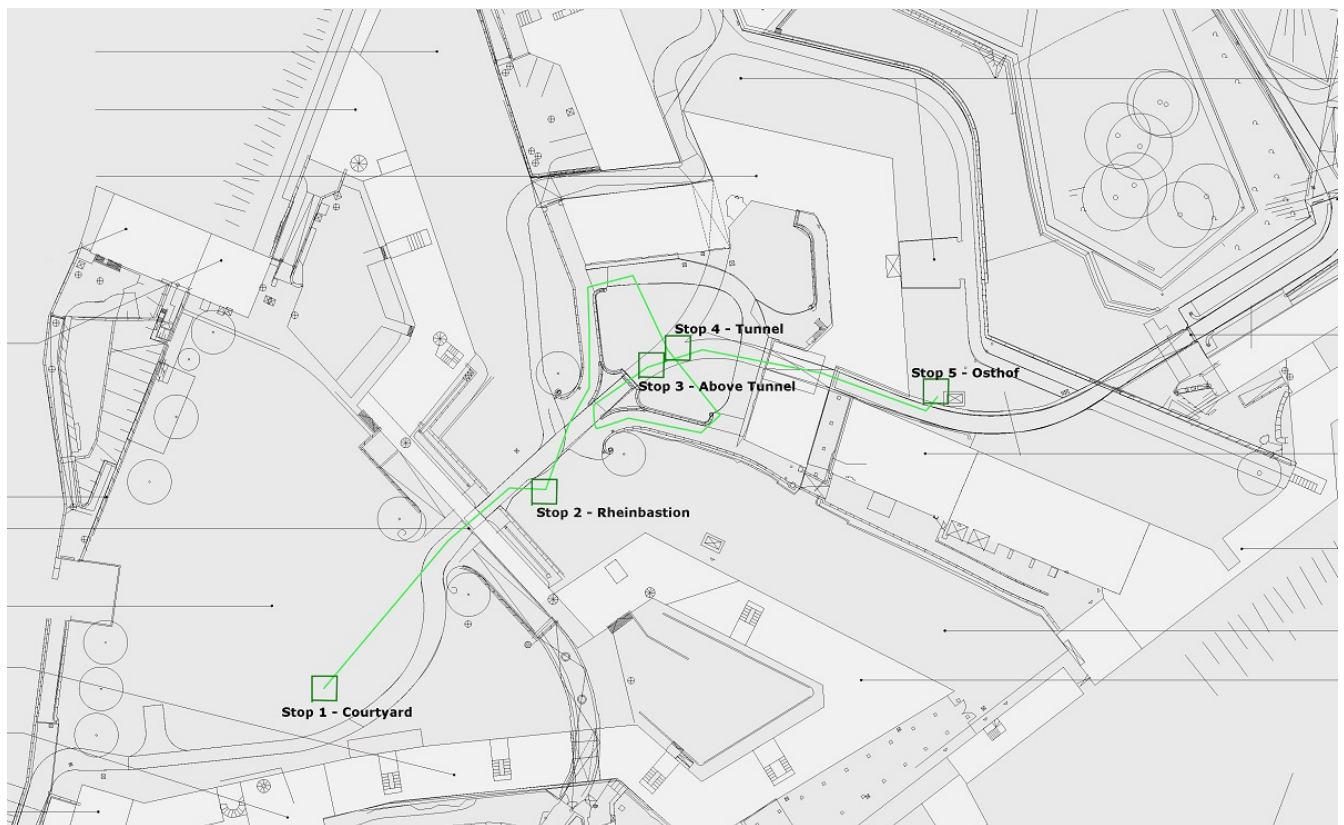
Figure 3.1: Path the experiment goes along © dwbrlp.de

3.2   Survey Questions

Formulating questions based on the five part structure, the route and the hypothesises mentioned over the previous sections was a time consuming task as striking a balance between difficulty and number per hypothesis meant revising the survey multiple times and made multiple pre tests on the real fortress necessary.

Gathering data for the prior real experiences needed in Hypothesises RQ 3a through RQ 3c was the target of the first set of questions. The first question was based on the idea that spatial navigation was influenced by the size of the city a person grows up in. As small cities with a few number of inhabitants and buildings are fairly easy to navigate on foot, a person

raised in a capital city would've be confronted with a complex network of streets and different possibilities to travel. As participants likely don't know the exact surface area a different indicator for city size was found in the number of inhabitants. While they most likely won't know the exact number and answers needed to be grouped during evaluation anyway, groups were predefined. The city classification by the Federal Statistical Office server as a basis for this and was adjusted to better differentiate between the city types. The next two questions focus more on specific activities which might help the spatial perception. An example for this is basic military training, which was mandatory in Germany up until July 2011. Over the course of this training, approaches to estimation of distance are taught and used throughout it. A similar selection of activities are also done during boy scouts where children are taught as well how to navigate terrain and estimate heights, albeit in an more age friendly manner. Having completed some kind of either this trainings might improve everyday estimations. The next pair of questions are based on Neidhardt and Popp [19] where evidence was found that there is a link between the spatial abilities of children and how active they are alone outside. This is further broken down by going to the school alone and just "roaming around" and influences angular pointing accuracy especially. To further build onto this and to test it in a different virtual environment these questions were added. One of them focuses on the age when they started to regularly visit places like school or nursery school alone, while the other focuses on the "roaming around" by asking for the irregular places like friends. The last pair of questions are based on the same link between the need to navigate along a path by oneself. As mentioned in the first questions large cities tend to have a variety of means to reach a given goal. One common example is driving the car or taking a public bus to the destination. Both of these are motorised transportation methods. However, while the bus is driven by a driver a car requires the own spatial skills related to finding the way to the destination. This idea was extended to include a range of transportation possibilities distinguished by how much the participants is involved in the process of finding the correct route. It was split based on the possession of a drivers license as there are only a limited number of ways to travel longer distances based on an own route without it.

The next section focused on questions related to the prior virtual experiences based on hypothesises RQ 3d till RQ 3f. These were broken down into several questions as opposing to a single "do you play a lot of videogames?" one to get a more accurate objective picture and a better data to look for links eg. based on time spent with videogames or genre preference.
The first three questions focused on gathering data about the personal favourite game and video game genre, with the former being split into "most enjoyed" and "most time spent on" which is, based on own experience, rarely the same. The latter was based on a predefined selection of major genres with participants asked to state any number of genres they enjoy. This questions was in part based on Procci et.al. [22] who found a relationship between gaming preference and the effectiveness of serious games, which this experiment falls under as well. The next set of questions are inspired by Subrahmanyam and Greenfield [23] who grouped participants by the number of days spent playing and duration of each session to look into the influence on spatial skills. As this experiment was focused on children the initial two questions were expanded to differentiate between childhood and current time, which makes a difference regarding the amount of spare time available. Besides these time focused question, a basic questions about the number of "proper" video games was added as well to further gauge the activity in the recent time period. The term "proper" was added to prevent inflation of results due to basic games found on social media which tend to have a smaller scope than a game developed over the course of years by a team of experienced developers. The final question for this section was focused on prior experience with HMDs and was added after the real experiments were conducted. The goal of this questions is to find out if prior usage of similar headsets improve the accuracy in the following sections.

The second section of the survey focuses on questions for hypothesises relating to spatial per-

ception (RQ 1) and peripheral perception (RQ 2). While most of these were asked during the main section, some of them required reflection (RQ 1c and RQ 2b) and were put towards the end of the survey together with the demographic questions. As spatial questions (RQ 1a, 1b, 1d) always focused on the current location, their peripheral counterparts (RQ 2a) focused on the last visited location and were asked before the spatial ones. Because peripheral perception tends to be short term, this order was chosen to reduce the number of information the participant could forget. Additionally hints about the size of non-tested structures were given before each set of questions. This helped reduce the range of answers and proved to be very helpful for the virtual tests. Questions related to the angular deviation (RQ 1d) were positioned between the peripheral and spatial as they also focus on a previous stop. Gathering data differed between the real and virtual parts, with the real portion using a custom build angular deviation device and the virtual part using custom scripts. Further details are explained in section 3.3.1 and 3.3.2.

At the first stop in the courtyard one estimation question about the height and one about the width of a structure was asked. Both of these relate to RQ 1b. As there was no prior stop no peripheral questions were available. Because participants could see the well the angular deviation question served more as a way of getting used to the device and to determine any baseline inaccuracies.

At the second stop in the "Rheinbastion" one peripheral question about the types of trees on the courtyard was asked followed by the angular deviation determination. Then three estimation questions relating to RQ 1b were asked with two of them focusing on height and one of them focusing on width.

At the third stop in the area over the tunnel two peripheral questions relating to features present in both previous stops were asked with one focusing on details in a wall of "Rheinbastion" and one going for a colour of tree buckets found throughout the fortress. After the angular deviation question two estimations relating to RQ 1b were made which focused on height and width.

At the next stop inside the tunnel two peripheral questions about the area over the tunnel were asked, with one of the focusing on a colour and one of them on a detail in the tested wall. This stop also served as the first of two barrier points. Following the angular deviation question three spatial estimation questions related to RQ 1a were held. These differ from the RQ 1b questions as the subject is asked to determine the distance between two points as well as the ceiling height and width of the tunnel they're in. RQ 1b questions in contrast focus more on the size of more distant objects.

At the final stop "Osthof" one peripheral question about a prepared sign in the tunnel was asked and the final angular position estimation was made. This was followed by two spatial estimation questions with one of each relating to RQ 1a and 1b.

After concluding the main section of the experiment data was gather for the remaining hypothesises RQ 1c and RQ 2b. To increase accuracy and avoid lengthy and difficult to evaluate descriptions both of these are based on the participants drawing onto a paper map of the fortress. The first one was tested by drawing the experiment path on a map without labels. The second one was tested by marking the location of certain structures. This also included the well which served as the target for the angular deviation question. Parallel to that notes were taken on the approach a subject took to working with the map which served as a basis for a map reading rating. It was also asked if they would get lost without a guide or a they think a child around the age 6 to 8 would get lost. These three questions are aimed to supplement the map drawing hypothesises.

The emotional questions were defined last, which contrasts their position in the survey. Measuring emotions is an extensive field with a variety of approaches discussed by psychology scholars. However, as this is only a part of the focus for this research the methods used are intentionally basic. One particular challenge is the approach on how the emotional state is assessed as this can influence the result. Directly asking the subject has the problem on measuring

or comparing answers. Also humans often have problems verbalising their current emotional state. An interesting way to circumvent this was proposed by Bradley and Land [24] who used a series of pictures to visualise different emotional states. However, using this method with more than three emotions proved to be time consuming in preparation and evaluation. A more efficient way was found by using the same indirect approach with carefully formulated text based questions, often based on what a subject would say to a different person. Determining the number of emotions was also not straight forward as there are a number of different approaches to classifying them with no one single being generally better than others. In the end the work of Plutchik [25] was chosen as it proposes an easy way of visualising the relations between emotions inspired by the colour wheel. As pictured in figure 3.2 he proposes four pairs of opposing positive and negative primary emotions based on the evolutionary process. They can also vary in their intensity. He further proposes eight intermediate emotions that are based on adjacent primary emotions. This way he defines 32 different emotions, while still maintaining a clear picture of the relations between them.

Initially it was intended to have questions for all eight primary emotions. However, two of them weren't applicable to this experiment. These are trust (positive) and sadness(negative). The remaining six served as the basis for seven survey questions with four of them aimed at positive emotions (joy, 2*interest, surprise) and three of them aimed at the remaining negative emotions (fear, annoyance and boredom). While six of those were held together at the area over the tunnel, the one about fear had to be asked later inside the tunnel as it was focus on the influence of the tunnel on the subject. To achieve better comparability and again avoid lengthy descriptions a five point Likert scale was used. The end representing disagreement was named "No, not at all" while the other end was named "Yes, definitely".
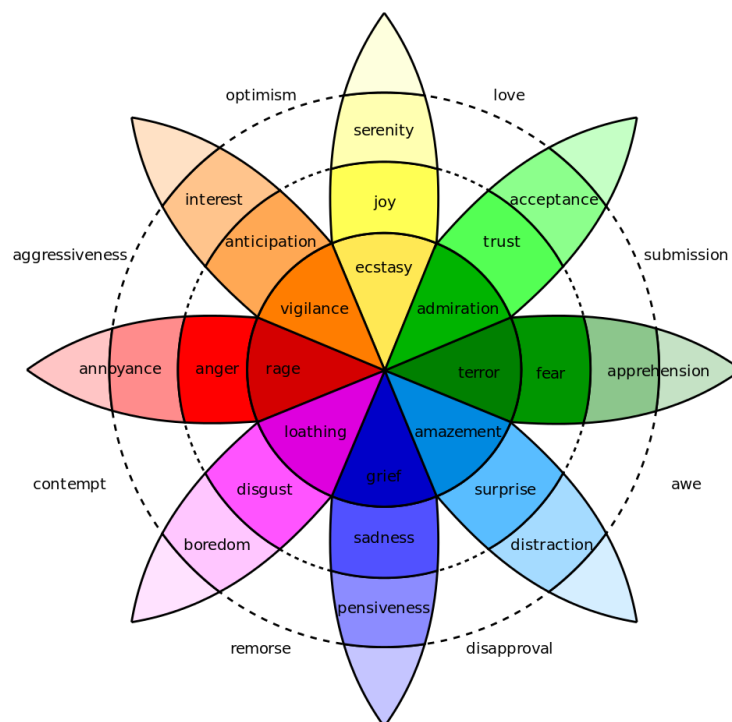
Figure 3.2: Plutchik's Wheel of Emotion as a guideline for the emotional questions

In the final section of the survey demographic questions were asked. The first one was to gather data about the number of visits in the last four years to the real fortress and aimed to find a correlation between this number and the accuracy of guesses. The time period was chosen, because wide areas of the fortress were changed for the "Bundgegartenschau" in 2011. The

next one was about the overall body height of the participant, which could impact the subjects perception in the virtual test. The next one was gender, which was found to have an influence on the spatial abilities related to the real and virtual world [26] [23]. To get a better overview of the dataset the age of the participant was also asked. An additional question was added during the virtual portion of the experiment gathering data about the course of study to uncover possible links between students studying computer science and having a higher amount of virtual experiences.

After the survey was completely flesh out it needed to be implemented in an environment where participants could easily access it. The most easy way of accessing it from everywhere is putting it online, which also avoids time consuming transcribing of paper based survey. After a comparison of major services, Google's Forms where chosen as they had a seemingly integration into Google Drive which in turn help further with the analysis of the data. As the survey was now web accessible, participants could enter there data directly via their smartphones. The final survey can be found in the appendix. Additionally along with the design process a series of pictures was created which matches real and virtual structures to their respective questions which can be viewed in the appendix.

3.3   Performing the experiment

3.3.1   Real part

Performing the experiments on the real fortress was more complex compared to the virtual model especially as there was no funding available.
Firstly, there needed to be a way to get to it for free within a reasonable time. Most of the participants were allowed the use of the public transport from the city to the base of the mountain. From there an also free inclined lift was taken to an entrance. Getting gratis access to the area itself was another challenge. As this series of experiments was unprecedented there was no contact person available at the beginning. After a short search the appropriate department inside the "Generaldirektion Kulturelles Erbe Rheinland-Pfalz" could be found and an agreement with the "Direktion Burgen Schlösser Altertümer" could be made to exempt participants from the entry fee.
Another external problem was the amount of daylight and weather. As the tests were held during autumn / winter 2015 there were few opportunities to perform test especially because they can take up to two hours in total. This was resolved by starting in the early afternoon with the goal of finishing before sunset and keeping participants informed about the weather situation and it's influence on the tests times. Another limitation was that all participants needed to enter at the same time. This raised problems as it was intended to only have one participant at a time taking the test. However, this would've potentially introduced a large delay for the last members of group as a single tests took around 45 minutes to one hour. This was solved by increasing the number of subjects per experiment run to two, which worked well the online survey which allowed participants to enter their answers directly. This made it possible to increase the total groupsize to four as the tests would now the over in half the time. For those without a smartphone a printed out version was provided on demand. To prevent one participants answer biassing the other ones they were instructed to not talk to each other about there estimates.
To conduct the actual test some tools were needed. Besides standard writing equipment (pens, clipboards, printed out maps etc.) this also included some printed out surveys. The reason for this was the poor mobile network coverage and empty smartphone batteries that created a constant demand for these. The main tool used for the experiment was the angular deviation device built by and loaned from the department of psychology as show in figure 3.3. This simple yet useful device allowed participants to point out the position of the well, while being able to directly read a value. This is accomplished by aligning the disk towards north based

on the integrated compass (red part). The resulting value was then compared against the actual bearing between the GPS coordinates of the stops and the well to calculate the angular position. These GPS points were determined in a prior step which also included calculating the correct dimensions of the structures. While the former could be done with a smartphone, the latter again required some help form the maintainers of the fortress as the plans were not publicly available. After an additional search the appropriate department "Stabsstelle Bau und Technik" was found. During a meeting with employees the heights were combined through a combination of official plans and on site measurements.

Figure 3.3: The purpose build Angular Deviation Device

Next the approximated locations for the single questions as well as the location of the stops themself needed to be translated into actual positions. This happened during the pre test phase. In three cases the stops were identified via GPS, while two locations allowed an orientation based on present landmarks.

The test procedure for the real portion was based on the general structure of the survey. After going to the start point (court yard) a small summary about the purpose and the goal of the experiment was given. After this participants fill out the first section concerning prior real and virtual experience. This was followed by the main portion. At first any peripheral questions about the previous stop were asked, then hints about the present scale of things were given which was followed by estimating the sizes and lastly going to the next stop. After the last stop the final portion began where participants drew the maps and answered some final questions. When the test was completed, everyone received some sweets for taking part after which they were free to explore the fortress.

The tests themself went well and participants had fun despite the rather high organisational overhead. Participants were recruited by directly approaching them and via a notice in collaboration with the department of psychology which granted them a confirmation of taking part in an empirical tests. Finding timeslots was done with the help of the appointment scheduling service doodle [1]. This turned out to be not the optimal way as participants had very only limited time and most of them had formed groups with a friend already. Keeping the pairs from talking about test results was manageable as most understood the idea behind this limitation. Keeping the sign up inside the tunnel proved harder than expected. This was either

---

[1] http://doodle.com, last access 19.04.16

due to employees removing it or because of the number of visitors. This sometimes led to a break around the middle of the test to put the sign back up. Another unexpected obstacle came up shortly before the tests started in late November. As Christmas was drawing closer a celebrations tent was erected in the courtyard which blocked the intended location for the first stop. This was handled by shifting the stop to an available position and remeasuring it's GPS coordinates. Initially it was intended to record some first person perspective video footage of participants taking the test with the help of an action cam. However, due to problems with the availability of the necessary equipment in the end only one test could be recorded. Figure 3.4 shows a selection of pictures where the tests is currently being completed. (A) shows subjects estimating the width of the kurtine with the angular deviation device between them marking the location of the stop. Additionally the aforementioned tent is visible to the right. (B) shows the estimation of the wells position with the help of the angular deviation device. (C) shows the participants estimating the height of the wall in front of them. Note how one uses his thumb as a reference. (D) shows the estimation of the tunnels width as well as the often overlooked symbol in the side tunnel to the right. (E) shows the estimation of the width of the path. The stop was so close to a wall to function as a barrier point. (F) shows an overview of the whole fortress with parts some stops like the courtyard visible.

(a) Courtyard

(b) Rheinbastion

(c) Over Tunnel

(d) Tunnel

(e) Osthof

(f) Overview © Google

Figure 3.4: Participants completing the real tests and an Overview of the testing area

3.3.2   Virtual part

Performing the virtual tests on the HMD and TV was more straight forward as it was held on uni campus inside the lab.

These circumstances allowed for a more flexible approach to scheduling the test with a lower amount of lead time required. Instead of using doodle, participants would respond to the notices (both at uni as well as on social media) and were assigned to agreed timeslot over the course of the day. While the lab itself was shared with other uni projects, it was always possible to use the same equipment.

The equipment needed for these test was, beside basic pen and map, mostly of technical nature. The program for both variants ran on a very powerful custom build computer with an Intel i7-6700 quad core CPU with a baseclock of 3.4 GHz and a Nvidia GeForce GTX Titan X GPU with 12 GB Video Buffer. The 4K TV used was a 55 inch model by LG (55UB850V), the HMD an Oculus Rift DK2, which both used a pair of generic stereo speakers for audio playback, and the gamepad used was a Microsoft Xbox 360 Wireless one.

As intended the survey stayed mostly the same with some minor additions to better capture the relevant prior virtual experiences. As with the real tests determining the answers was not as straight forward. As mentioned in 2.4 the scale of the model was not consistent and varied significantly from area to area. This required to measure the different objects in the virtual model and applying a common scale factor which in turn led to different set of correct values with the height of the well have a notable difference between real and virtual. Similar to the real description in the previous section, a set of pictures was created to map the survey questions to the virtual places and put in the appendix. HMD users encountered a problem as they're not able to fill in their answers into a real world survey. This was circumvented by letting them say the answers out loud and then writing them down. The stops were marked with white platforms matching the locations of the real experiment. The experiment steps where largely the same as in the real parts including the possibility to explore the rest of the virtual fortress afterwards. The only difference was that the HMD needed to be adjusted to the participant. This was done with the help of a demo scene provided by the Oculus SDK. The angular deviation was measure with a custom script which, in contrast to the real part, immediately determined the angular deviation between the facing of the player and the well. It was triggered by a button press on the participants gamepad. Due to the virtual environment it was easier to record tests showing where participants look and which paths they take when following the guide.

Tests themself went good and participants had fun especially the ones using the HMD. Some TV users were initially disappointed that they couldn't use the HMD. To balance this out all of them were given the opportunity to freely explore the HMD version after their test was completed. During some test in game footage was captured in hopes of additional insights later on. As the tests were held in a shared space a minor number of tests had to pause to allow others to use the equipment in urgent cases. Interestingly some participants used the virtual cross hair to put the hints into a better perspective. As this happened in a similar way to real participants using their thumbs this approach was not prohibited, but also not encouraged. Figure 3.5 shows participants taking the virtual test using the aforementioned hardware. As the TV hung in a rather low position TV users as in (A) completed the test seated, whereas their HMD counterparts (B) stood. Pictures of the virtual stops themself can be found in figure 2.3

(a) TV Test   **(b)** HMD Test

Figure 3.5: Participants completing the virtual tests

3.4   Data Analysis

Preparation of the dataset was done with Microsoft Excel 2010 prior to the import into the statistics software. The goal was to unify the answers as for example the survey was filled out in two languages in two slightly different variants (Real and Virtual).

As the German survey was the most commonly used the first step was to translate all answers into German and adapting them to the language conventions eg. which symbol is used as a decimal point. During this any typographical errors have been also corrected. The next step was to group similar string based answers together most notably in questions including colours and video game preferences. As a next step some answers were recoded into numerical values to allow an interpretation. A good example for this is the question about the symbol in the side tunnel. Initially just a description of what participants thought they saw, it was converted into a four point system, one for each significant feature of the symbol. If one answer states any three features, it receives three out of four points, thus converting this nominal variable into an ordinal one. In another step any missing values were declared, which accounted for missing data points as well as the participant not knowing the answer and specifically replying that there was nothing of interest. Besides the transcoding of nominal to ordinal variables most of the height estimation variables needed some improvements as well. Based on the correct value a deviation variable was created for each one. If a participant guessed the size of an object correct then this value is 0, but if he over- or underestimated this values it became positive or negative. This allows for a better representation of the answers, as the actual height of the objects varied between the real world and it's virtual counterpart. Another set of derived variables are the ones related to the angular position of the well for the real tests. Based on the GPS coordinates of the stops and well the relative position of each stop to the well was calculated. It then was subtracted from the answers with the resulting amount forming a new set of angular deviation variables with values alike to those from the virtual tests. This step was not needed for the virtual tests because the deviation value was measured directly during the test.

After importing the data into SPSS, only the level of measurement needed to be determined. Additionally some slight changes to the variable names where made as the software doesn't support space characters for these. Over the course of the analysis additional changes to the dataset were made in order to get a better result for some hypothesises.

IBM's Statistics Software SPSS 23 was the main tool used for the statistical data evaluation. Based on the prepared Excel File different methods were applied to get an overview of the answers and find correlations in the different realities. For the majority of hypothesis this resulted in diagrams with three characteristics representing the different test environments. Over the course of the evaluation further changes to variables were made. Examples for this include converting string based variables to numerical ones in order to have a wider selection of methods available.

During the analysis mainly three types of diagrams were used. For one the Boxplot diagram

to get an overview of the characteristics of an answer. Not only do they show the median of responses, but also the distribution of answers. Most of the time they're based on a derived variable, which contains the deviation from the correct value. A positive value indicates that the answer was above the correct value, while a negative one shows the opposite. This allows putting the point of origin in the centre of the x-axis to improve readability. In some other cases they represent a five point Likert scale, which also has it midpoint in the centre of the x axis.

To get an overview of string based variables, pie charts were used as they give a good impression over the answers made as well as their proportions. This is especially useful as the sample size was different across the different types of tests. When they are used on colour based questions, the pie segments also match the colour of the answer to get an even better outline of the given answers.

The third and final type is a bivariate correlation matrix. It is used to find links between answers and determine how strong and in what ratio they are. Two level of significances are used: a normal one which uses the common 5% significance to indicate a non-random correlation (marked in yellow) and a stricter one which uses a 1% significance level (marked in orange). They're both two tailed to find negative and positive correlations. The correlation coefficient used was Kendall's Tau B as this allows finding links across variable types and is more robust against outliers than Spearman's Rho.

As mentioned additional work with the variables was needed during the analysis. One case was the recoding of a string to a numerical value both for yes/no answers as well as more complex multiple choice ones. In one specific instance this required splitting one variable into all it's possible answers and assigning a Yes/No flag where it applied to the answer. Besides this also some additional grouping of variables was needed to further improve the quality of answers. Most of this additional work needed to be done for research Question 3.

As two hypothesis were based around drawing on a physical map, a different approach was needed for evaluation. The best approach to visually compare all paths taken in a reality was to create a heatmap from all answers. This was done by scanning in the paper maps and with the help of the image manipulation software GIMP. First all maps had their drawn path virtually traced with a light colour. Then they were aligned over each other so that in a final step all virtual paths were visible. When a given path occurred more than once it's colour would automatically turn a shade darker with the darkest path being the most common one. Finally a red line was added which shows the correct path. A Screenshot of this process can be seen in figure 3.6
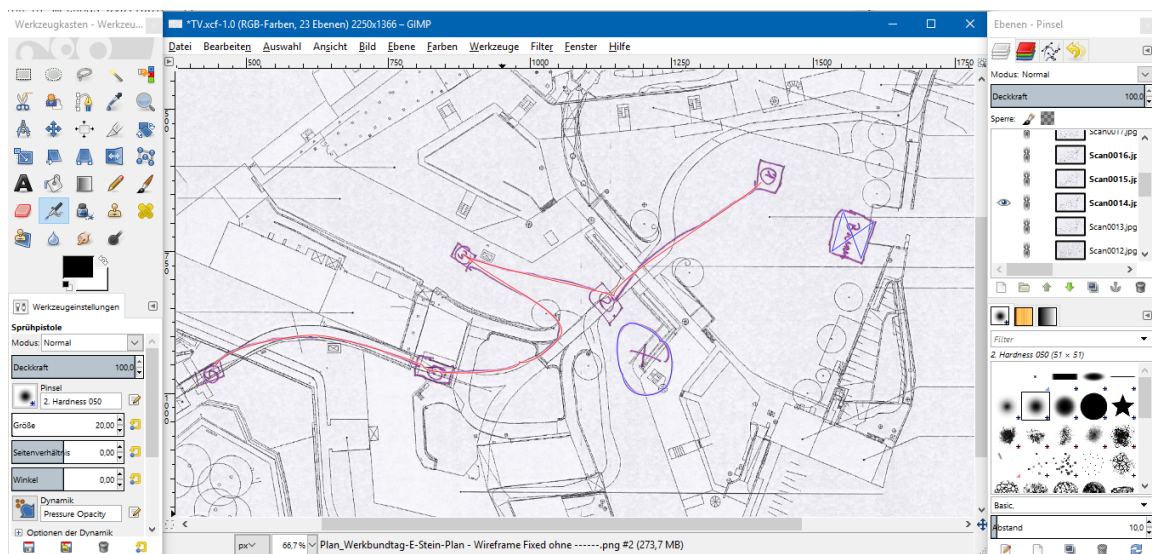
Figure 3.6: Tracing the paths from scans using GIMP

In total 60 tests were made with 16 of them on the real fortress, 20 with the TV and 24 with the HMD. An overview of some key figures grouped by the test environment is displayed in figure 3.7.

Age is somewhat representative for university students and ranges from early 20s until early 30s with two exceptions for real tests. However, this doesn't affect the median too much as this tests also contains younger participants and it's the same for the TV test.

While Gender was almost evenly distributed across the whole data set, looking at the distribution inside that tests shows a different picture. Real tests had unproportional more females than males, whereas the opposite was true for TV. Only the HMD tests had a balanced distribution.

The tests took place during two time windows between 2015 and 2016: the real tests were conducted from mid-November till beginning of December on the real fortress. The HMD and TV were held between end of January and end of February at university campus.

A goal was to keep the number of fortress visits in the last four years under five. While this was accomplished by HMD and TV tests, the real tests included some answers up to ten.

The reason that the distributions are uneven and some goals couldn't be met lies in the challenge of finding participants without research funding especially for the real tests as these involved a significant time overhead related to transportation.

(a) Age

(b) Gender

(c) Time Period

(d) Number of fortress visits in last four years
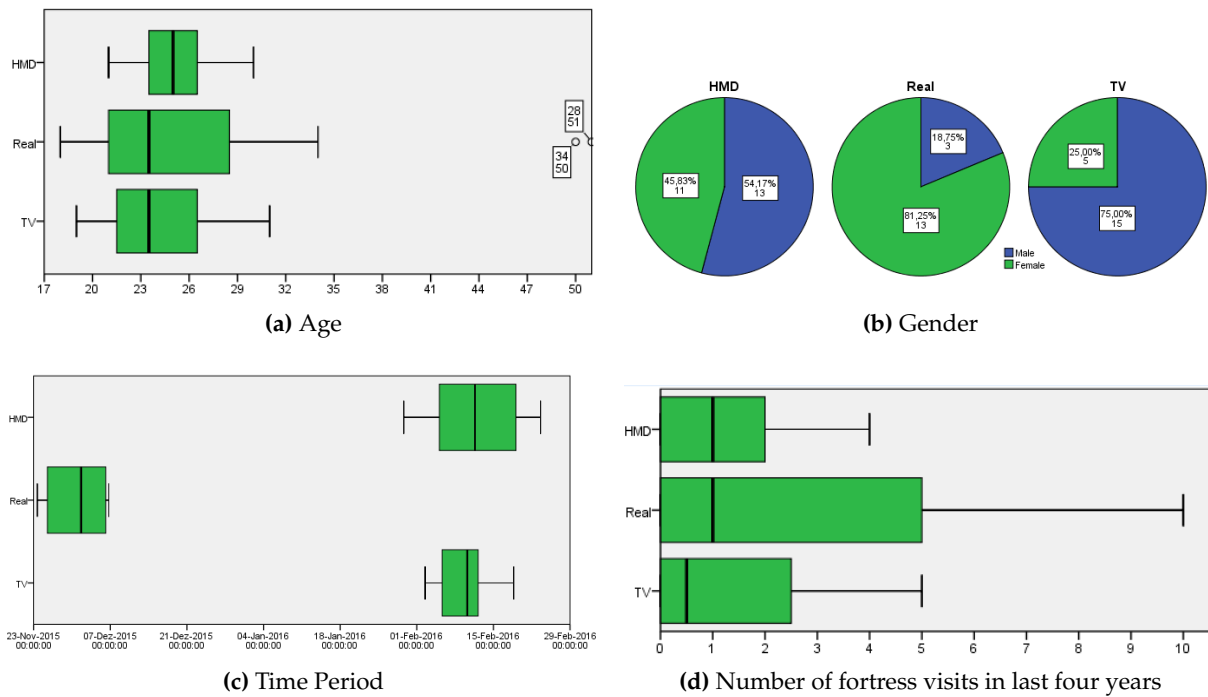
Figure 3.7: Distribution of age, gender, time period and number of fortress visits

3.4.1   Results for research question 1

As mentioned in previous parts 1.3 and 3.2 the first research question "How is the spatial perception influenced?" was tested with four different hypothesises. These were checked with a different number of survey questions ranging from four to seven each. The answers to these questions form the basis for a number of Boxplots. These are supplemented by correlation matrices which point out any links between two answers.

Results for hypothesis RQ 1a   The hypothesis "The error in estimating is significantly different when judging distances" was tested with four survey questions which are shown in the corresponding Boxplots and tables in figure 3.8 and 3.9.

The answers have a general tendency of underestimating the distances particularly in the HMD

and TV Tests. The results in (A) are similar with real tests having a bit lower difference from the median. Answers to (B) were a bit more different. While HMD and TV still tend to underestimate, Real now tends to overestimate. HMD and Real have a similar amount of variation, but the median of TV is actually closest to the correct value. (C) is much like (B) with the median of the real tests being close to the correct value. Finally, (D) is similar to (A) with the medians of the answers being closer to the correct value and the Real test having lowest deviation and closest median.

In general it can be said that the Median of HMD is closer to the one of TV than to Real. Looking at the difference in answers, HMD has in three out of four questions a similar or lower value than TV matching the Real answers.

Considering the correlations tables shows a similar picture as TV has the most links, Real not a single one and HMD situated in the middle with three out of five. Also HMD has the highest number of very significant matches with two out of three. Interesting to note is that all significant pairs are positive.

(a) What's the distance between the Floor lights?

(b) How high is the tunnel?

(c) How wide is the tunnel?

(d) How wide is the path towards the tunnel?
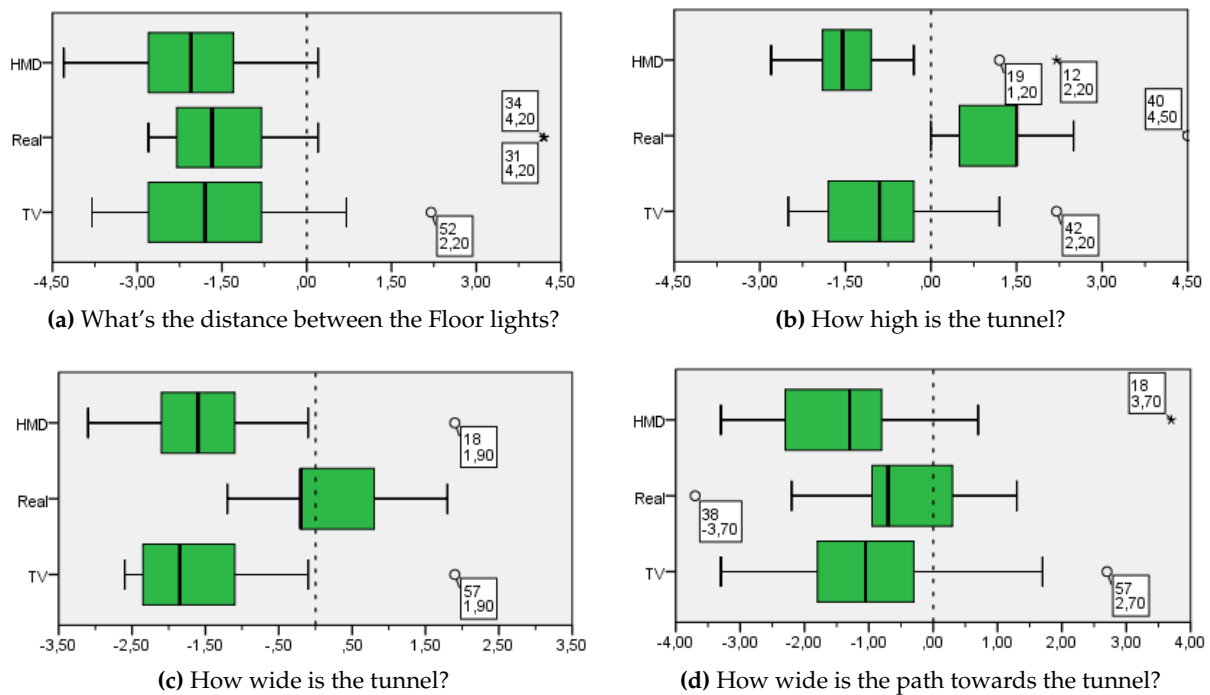
Figure 3.8: Results of research question 1a as deviation from correct value

			What's the distance between the Floor lights in m? (Deviation)	How high is the tunnel in the middle in m? (Deviation)	How wide is the tunnel in m? (Deviation)	How wide is the path towards the tunnel in m? (Deviation)
Kendall-Tau-b	What's the distance between the Floor lights in m? (Deviation)	Korrelationskoeffizient	1,000	,279	,385*	,553**
		Sig. (2-seitig)	.	,088	,020	,001
		N	24	24	24	24
	How high is the tunnel in the middle in m? (Deviation)	Korrelationskoeffizient	,279	1,000	,128	,064
		Sig. (2-seitig)	,088	.	,435	,695
		N	24	24	24	24
	How wide is the tunnel in m? (Deviation)	Korrelationskoeffizient	,385*	,128	1,000	,532**
		Sig. (2-seitig)	,020	,435	.	,001
		N	24	24	24	24
	How wide is the path towards the tunnel in m? (Deviation)	Korrelationskoeffizient	,553**	,064	,532**	1,000
		Sig. (2-seitig)	,001	,695	,001	.
		N	24	24	24	24

(a) HMD

Kendall-Tau-b			What's the distance between the Floor lights in m? (Deviation)	How high is the tunnel in the middle in m? (Deviation)	How wide is the tunnel in m? (Deviation)	How wide is the path towards the tunnel in m? (Deviation)
	What's the distance between the Floor lights in m? (Deviation)	Korrelationskoeffizient	1,000	,059	,093	-,059
		Sig. (2-seitig)	.	,774	,661	,775
		N	16	16	16	16
	How high is the tunnel in the middle in m? (Deviation)	Korrelationskoeffizient	,059	1,000	,137	,141
		Sig. (2-seitig)	,774	.	,520	,498
		N	16	16	16	16
	How wide is the tunnel in m? (Deviation)	Korrelationskoeffizient	,093	,137	1,000	,115
		Sig. (2-seitig)	,661	,520	.	,587
		N	16	16	16	16
	How wide is the path towards the tunnel in m? (Deviation)	Korrelationskoeffizient	-,059	,141	,115	1,000
		Sig. (2-seitig)	,775	,498	,587	.
		N	16	16	16	16

(b) Real

Kendall-Tau-b			What's the distance between the Floor lights in m? (Deviation)	How high is the tunnel in the middle in m? (Deviation)	How wide is the tunnel in m? (Deviation)	How wide is the path towards the tunnel in m? (Deviation)
	What's the distance between the Floor lights in m? (Deviation)	Korrelationskoeffizient	1,000	,422[*]	,280	,365[*]
		Sig. (2-seitig)	.	,018	,124	,039
		N	20	20	20	20
	How high is the tunnel in the middle in m? (Deviation)	Korrelationskoeffizient	,422[*]	1,000	,365[*]	,351[*]
		Sig. (2-seitig)	,018	.	,042	,045
		N	20	20	20	20
	How wide is the tunnel in m? (Deviation)	Korrelationskoeffizient	,280	,365[*]	1,000	,556[**]
		Sig. (2-seitig)	,124	,042	.	,002
		N	20	20	20	20
	How wide is the path towards the tunnel in m? (Deviation)	Korrelationskoeffizient	,365[*]	,351[*]	,556[**]	1,000
		Sig. (2-seitig)	,039	,045	,002	.
		N	20	20	20	20

(c) TV

Figure 3.9: Correlations between the answers of research question 1a

Results for hypothesis RQ 1b The hypothesis "The error in estimating is significantly different when judging the size of a room/area" was tested with eight survey questions which are shown in the eight corresponding Boxplots in figure 3.10 as well as in three tables in figure 3.11.

Most of the answers again underestimate the sizes, but more similarly than in the previous paragraph. Looking at the first set of Boxplots (A), HMD and TV are similar with HMD having a slightly lower deviation from the correct value, but with TV having a closer median. Answers made in the real tests are both more accurate and have less fluctuation around the median. The Real answers to (B) have a lot of spread to them, while still maintaining a similar median like HMD and TV. HMD has the closest median, while TV has the smallest range around it. In (C) TV tests yielded the closest match, while again having the lowest range of answers. The median of Real is the lowest and the answers have the most spread. HMD answers are in the middle of it. HMD and TV answers for (D) mimic each other with Real again having the highest amount of spread in the answers and all medians being close together.

Moving over to the second figure (E) this time HMD and TV got a higher deviation than Real, especially TV with three spike answers. HMD's median is closest to the correct value. In (F) HMD and TV got a comparably high amount of spikes and a similar amount of spread with HMD's median again being the closest to 0. Real values have lower variation, but the median is also the furthest away. In (G) HMD and TV have a similar close median with some spikes, while TV also got the lowest variation. The variation of HMD is similar to the one of Real. (H) is somewhat special as the HMD answers to this question resemble the ones made in the real test, both in their median as well as in their variation. While TV has a similar median, it's

variation is visibly higher than the one from HMD.

In general it can be said that the medians of HMD questions are closer to the TV ones. Interesting to note is that these medians are in most of the cases closest to the correct value, although with a higher deviation than Real has. In (A) and (D) HMD results are similar to TV, but in (B) and (C) they are in the middle between Real and TV Test. (H) is a rare case in which HMD is actually more similar to Real than TV.

Moving over to the matrices HMD now tends to be situated more in the middle between Real and TV. It shares the same number of links found with TV including a very significant one, but Real has a similar count as well. Looking at the links, itself HMD shares one each with TV and Real with both of them being positive and related to estimating height.
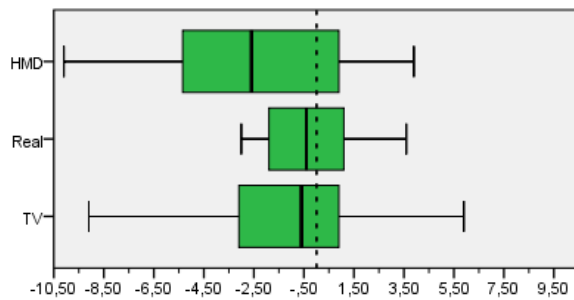
(a) How high is the well?
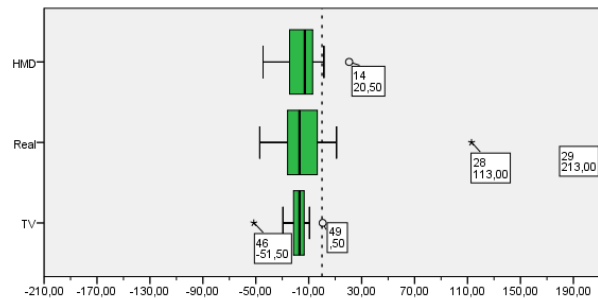
(b) What is the width of the kurtine?
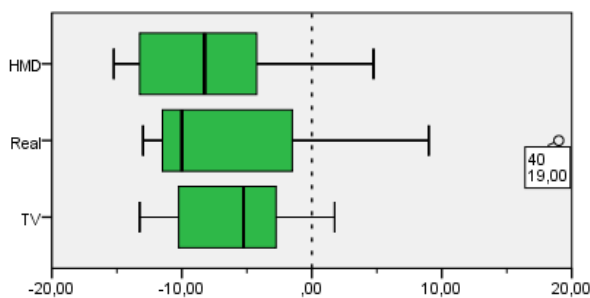
(c) How high is the smaller tree in front of the tunnel?
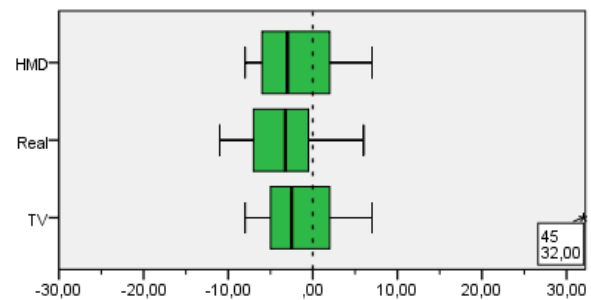
(d) How high is the wall with the arrowslits?
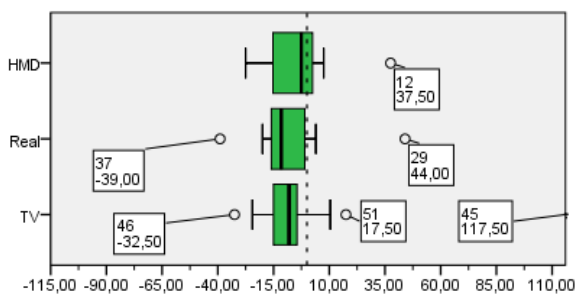
(e) How wide is the wall with the arrowslits?

(f) How high is the wall with the 4 Columns?

(g) How wide is the wall with the 4 Columns?   **(h)** How high is the opposite wall?
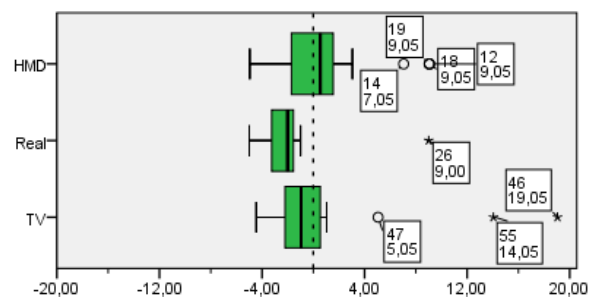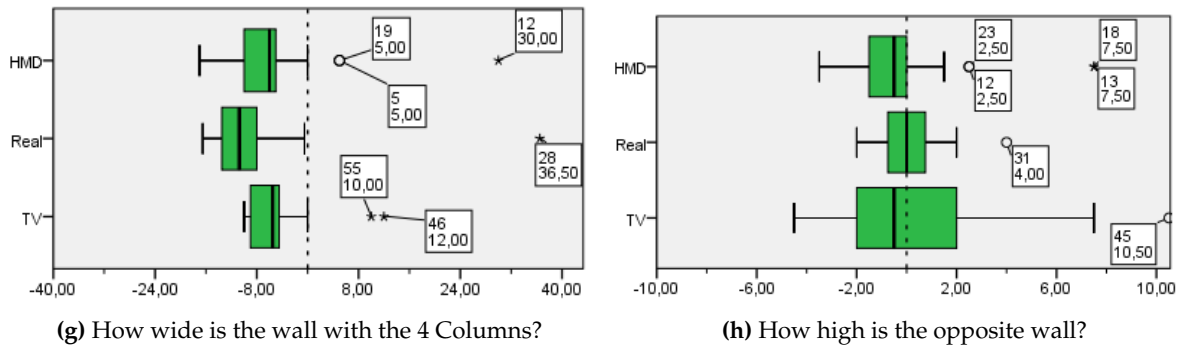
Figure 3.10: Results of research question 1b as deviation from correct value

Kendall-Tau-b

		How high is the well in m? (Deviation)	How wide is the Kurtine in m? (Deviation)	How high is the smaller tree in front of the tunnel in m? (Deviation)	How high is the wall with the arrowslits in m? (Deviation)	How wide is the wall with the arrowslits in m? (Deviation)	How high is the wall with the 4 Columns in m? (Deviation)	How wide is the wall with the 4 Columns in m? (Deviation)	How high is the opposite wall in m? (Deviation)
How high is the well in m? (Deviation)	Korrelationskoeffizient	1,000	,042	,115	,371*	,183	,339*	,175	,291
	Sig. (2-seitig)	.	,782	,461	,016	,229	,028	,255	,065
	N	24	24	24	24	24	24	24	24
How wide is the Kurtine in m? (Deviation)	Korrelationskoeffizient	,042	1,000	-,004	,158	,113	-,032	,084	-,066
	Sig. (2-seitig)	,782	.	,980	,311	,464	,839	,593	,680
	N	24	24	24	24	24	24	24	24
How high is the smaller tree in front of the tunnel in m? (Deviation)	Korrelationskoeffizient	,115	-,004	1,000	,557**	,096	-,062	,196	,115
	Sig. (2-seitig)	,461	,980	.	,000	,541	,700	,217	,482
	N	24	24	24	24	24	24	24	24
How high is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	,371*	,158	,557**	1,000	,188	,269	,204	,125
	Sig. (2-seitig)	,016	,311	,000	.	,225	,088	,194	,438
	N	24	24	24	24	24	24	24	24
How wide is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	,183	,113	,096	,188	1,000	,316*	,473**	,135
	Sig. (2-seitig)	,229	,464	,541	,225	.	,043	,002	,396
	N	24	24	24	24	24	24	24	24
How high is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	,339*	-,032	-,062	,269	,316*	1,000	,032	,159
	Sig. (2-seitig)	,028	,839	,700	,088	,043	.	,838	,325
	N	24	24	24	24	24	24	24	24
How wide is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	,175	,084	,196	,204	,473**	,032	1,000	,293
	Sig. (2-seitig)	,255	,593	,217	,194	,002	,838	.	,070
	N	24	24	24	24	24	24	24	24
How high is the opposite wall in m? (Deviation)	Korrelationskoeffizient	,291	-,066	,115	,125	,135	,159	,293	1,000
	Sig. (2-seitig)	,065	,680	,482	,438	,396	,325	,070	.
	N	24	24	24	24	24	24	24	24

(a) HMD

Kendall-Tau-b

		How high is the well in m? (Deviation)	How wide is the Kurtine in m? (Deviation)	How high is the smaller tree in front of the tunnel in m? (Deviation)	How high is the wall with the arrowslits in m? (Deviation)	How wide is the wall with the arrowslits in m? (Deviation)	How high is the wall with the 4 Columns in m? (Deviation)	How wide is the wall with the 4 Columns in m? (Deviation)	How high is the opposite wall in m? (Deviation)
How high is the well in m? (Deviation)	Korrelationskoeffizient	1,000	-,035	,507**	,291	,018	-,131	,098	,164
	Sig. (2-seitig)	.	,856	,009	,132	,927	,511	,614	,405
	N	16	16	16	16	16	16	16	16
How wide is the Kurtine in m? (Deviation)	Korrelationskoeffizient	-,035	1,000	-,121	-,026	,487*	,073	,182	-,035
	Sig. (2-seitig)	,856	.	,524	,892	,011	,709	,339	,854
	N	16	16	16	16	16	16	16	16
How high is the smaller tree in front of the tunnel in m? (Deviation)	Korrelationskoeffizient	,507**	-,121	1,000	,439*	,222	-,102	,027	-,054
	Sig. (2-seitig)	,009	,524	.	,022	,252	,606	,891	,781
	N	16	16	16	16	16	16	16	16
How high is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	,291	-,026	,439*	1,000	,062	,388*	,061	-,009
	Sig. (2-seitig)	,132	,892	,022	.	,749	,049	,749	,963
	N	16	16	16	16	16	16	16	16
How wide is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	,018	,487*	,222	,062	1,000	,037	,187	,109
	Sig. (2-seitig)	,927	,011	,252	,749	.	,851	,335	,578
	N	16	16	16	16	16	16	16	16
How high is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	-,131	,073	-,102	,388*	,037	1,000	,075	,257
	Sig. (2-seitig)	,511	,709	,606	,049	,851	.	,707	,201
	N	16	16	16	16	16	16	16	16
How wide is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	,098	,182	,027	,061	,187	,075	1,000	-,199
	Sig. (2-seitig)	,614	,339	,891	,749	,335	,707	.	,308
	N	16	16	16	16	16	16	16	16
How high is the opposite wall in m? (Deviation)	Korrelationskoeffizient	,164	-,035	-,054	-,009	,109	,257	-,199	1,000
	Sig. (2-seitig)	,405	,854	,781	,963	,578	,201	,308	.
	N	16	16	16	16	16	16	16	16

(b) Real

Kendall-Tau-b			How high is the well in m? (Deviation)	How wide is the Kurtine in m? (Deviation)	How high is the smaller tree in front of the tunnel in m? (Deviation)	How high is the wall with the arrowslits in m? (Deviation)	How wide is the wall with the arrowslits in m? (Deviation)	How high is the wall with the 4 Columns in m? (Deviation)	How wide is the wall with the 4 Columns in m? (Deviation)	How high is the opposite wall in m? (Deviation)
	How high is the well in m? (Deviation)	Korrelationskoeffizient	1,000	,240	,459**	,444**	,074	-,192	,012	,041
		Sig. (2-seitig)	.	,169	,007	,009	,666	,268	,947	,814
		N	20	20	20	20	20	20	20	20
	How wide is the Kurtine in m? (Deviation)	Korrelationskoeffizient	,240	1,000	,431*	,114	,351*	,089	,088	-,213
		Sig. (2-seitig)	,169	.	,013	,508	,043	,614	,616	,227
		N	20	20	20	20	20	20	20	20
	How high is the smaller tree in front of the tunnel in m? (Deviation)	Korrelationskoeffizient	,459**	,431*	1,000	,270	,233	,086	,147	,086
		Sig. (2-seitig)	,007	,013	.	,108	,167	,618	,389	,618
		N	20	20	20	20	20	20	20	20
	How high is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	,444**	,114	,270	1,000	-,110	,159	,056	,329
		Sig. (2-seitig)	,009	,508	,108	.	,512	,353	,741	,054
		N	20	20	20	20	20	20	20	20
	How wide is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	,074	,351*	,233	-,110	1,000	-,171	,091	-,166
		Sig. (2-seitig)	,666	,043	,167	,512	.	,318	,596	,335
		N	20	20	20	20	20	20	20	20
	How high is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	-,192	,089	,086	,159	-,171	1,000	,262	,259
		Sig. (2-seitig)	,268	,614	,618	,353	,318	.	,132	,139
		N	20	20	20	20	20	20	20	20
	How wide is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	,012	,088	,147	,056	,091	,262	1,000	,239
		Sig. (2-seitig)	,947	,616	,389	,741	,596	,132	.	,170
		N	20	20	20	20	20	20	20	20
	How high is the opposite wall in m? (Deviation)	Korrelationskoeffizient	,041	-,213	,086	,329	-,166	,259	,239	1,000
		Sig. (2-seitig)	,814	,227	,618	,054	,335	,139	,170	.
		N	20	20	20	20	20	20	20	20

(c) TV

Figure 3.11: Correlations between the answers of research question 1b

Results for hypothesis RQ 1c The hypothesis "The error in estimating is significantly different when judging the walked distance" was tested with a printed out map of the fortress. After the main test participants were asked to draw their walked path onto this map, which was then scanned and combined with the others in GIMP. The heatmaps are shown in figure 3.12 with path colours ranging from light blue to marine blue. Furthermore, notes have been made during each test to rate the participants ability to read the map, find structures he/she saw during the tests and how long the completion took. The notes have been combined into a five point rating as shown in figure 3.13. This figure also contains the participants assesment if they'd have be able to do the tests alone (b) and if they think a child would've got lost on the fortress (c).

Comparing the maps around the starting area of stop 1, Real and TV answers aren't coherent enough to make out the actual starting position, while the HMD answers visibly converge around the correct area. Following the paths HMD and TV answers start to match up more as most of them found the right path up over the tunnel and down into it, while Real answers start to get more fuzzy. This leads to only some Real answers pointing out the correct end area at stop 5, while TV and especially HMD answers are closer to it. Outliers representing people who had trouble finding the correct paths are present in all of them with the virtual ones having more than the real one. Overall HMD and TV contain more accurate guesses than Real with only a minor increase in outliers.

The map reading rating somewhat supports these observations as TV participants had the least problems with finding their way and real ones having the most problems. HMD is situated in the middle between those two with a similar median as TV, but with a variation of answers as alike Real. Looking at the own assessment, HMD seems to be evenly distributed. However it's median is actually at "rather yes" in the same location as TV, albeit the latter as smaller range of answers and tends more to the confident side. Real is similar to HMD in this regard as they both share the same range of answers, but with Real having a median value of "balanced". The assessment if a child would get lost is generally similar across all realities with TV participants being the very confident and HMD and Real having more doubts. However, these are still far outweighed by the confident answers.
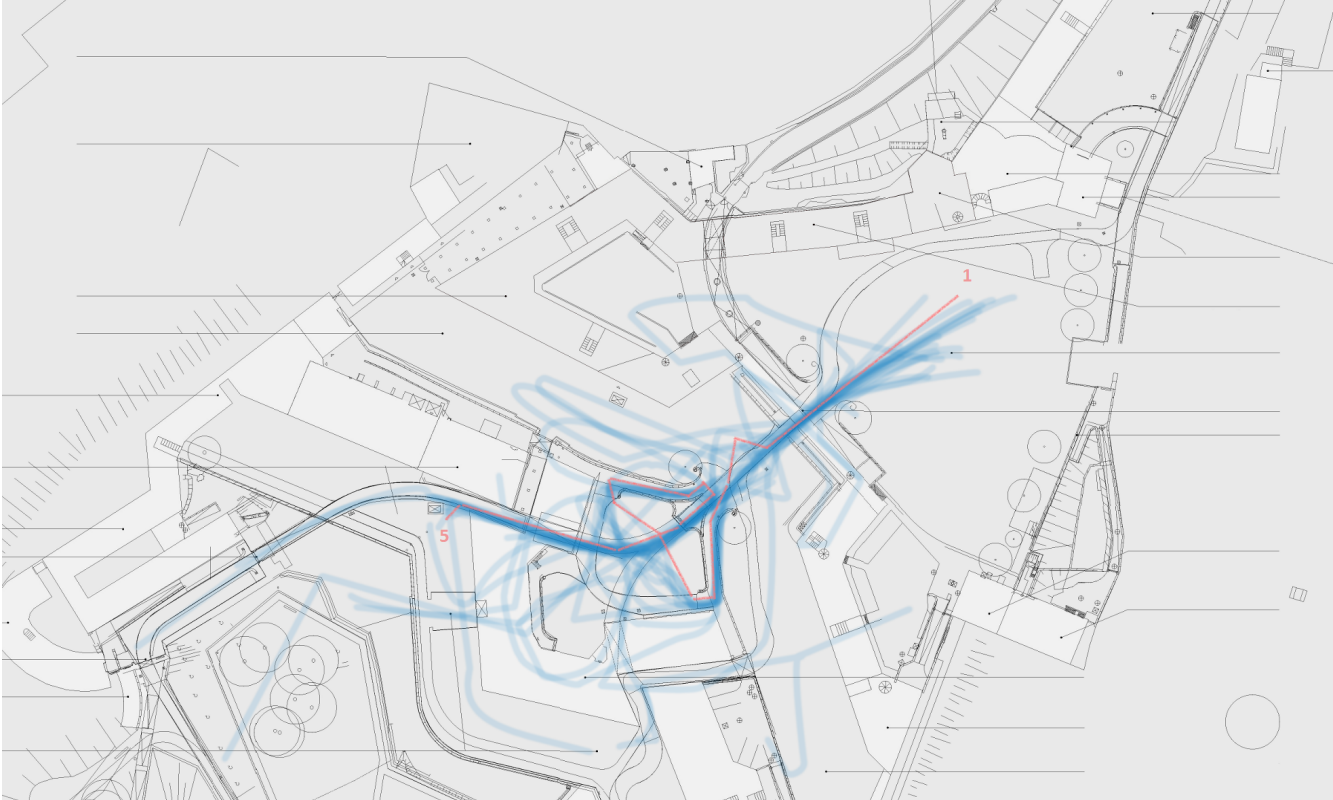
(a) HMD paths

(b) Real paths
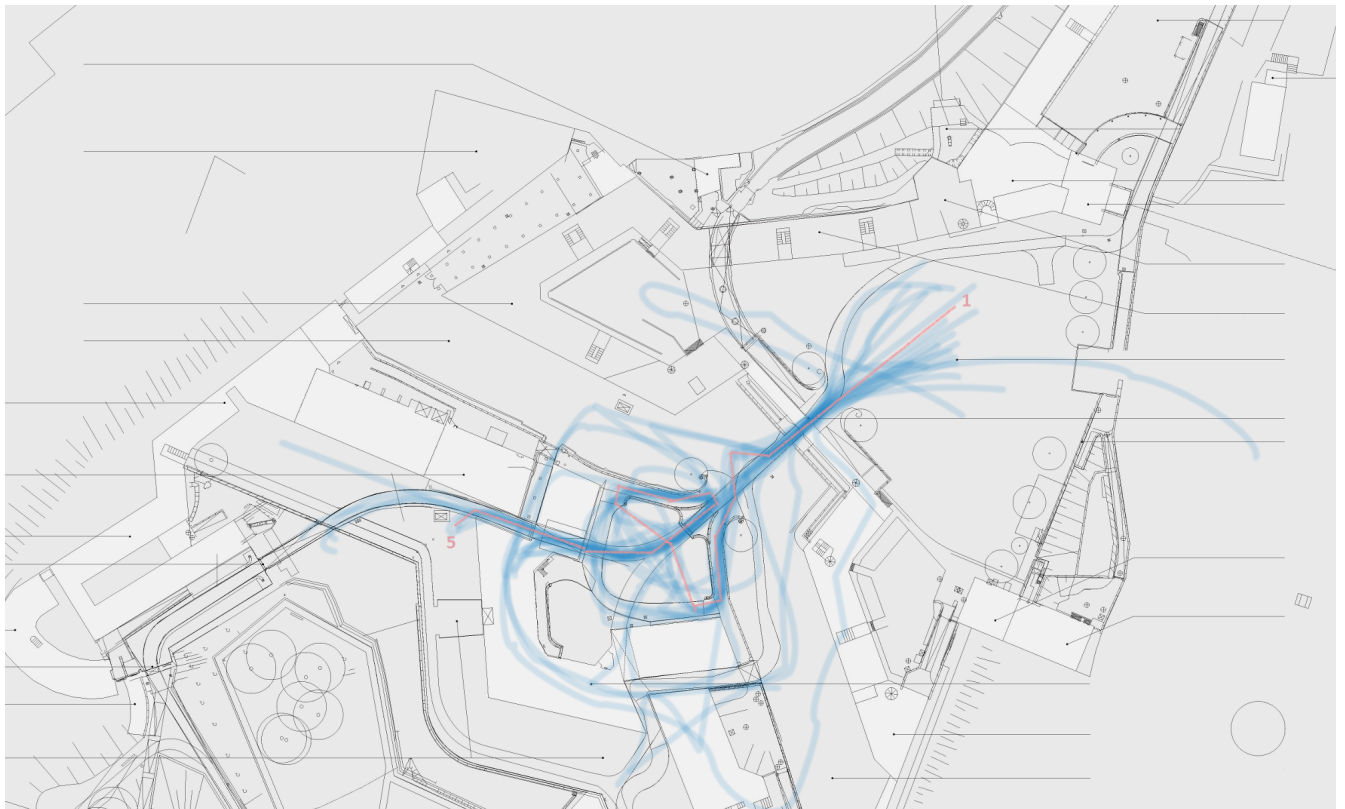
(c) TV paths

Figure 3.12: Results of research question 1c as a Heatmap TV
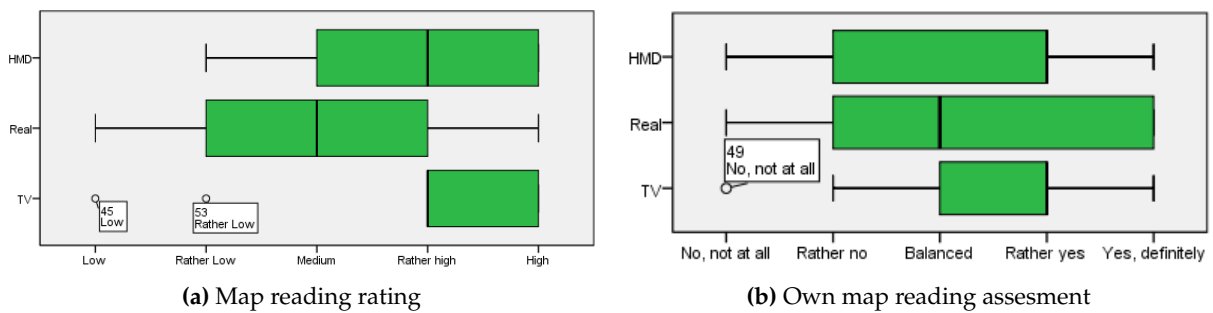
(a) Map reading rating

(b) Own map reading assesment
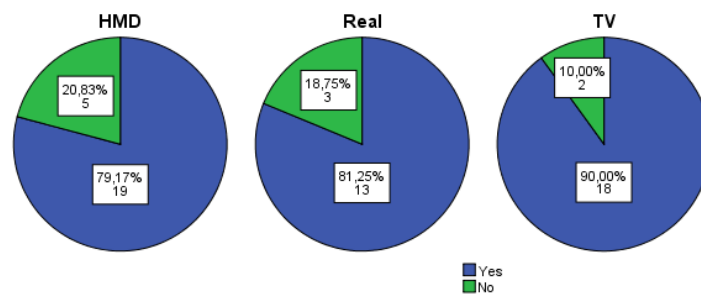
(c) Map reading assesment based on child

Figure 3.13: Additional data regarding the map reading skills

Results for hypothesis RQ 1d The hypothesis "The error in estimating is significantly different when judging the angular position of points" was tested with five survey questions which are shown in five Boxplots and three tables in figures 3.14 and 3.15.

Of special note is that the precise location of the stops in the real world varies slightly. Even a variation of a few meters due to GPS's error of measurement can lead to a deviation of 5°. This is particularly noticeable at stop 1 as guesses are unusually spread out, despite the participants being able to directly see the well. As distance to the well grew this became less of a problem so stops 2 to 5 weren't affected. Furthermore, answers during Real test were rounded to 5°, while the answers during HMD and TV test weren't rounded. The reason for this is the way the angular deviation was determined as the angular measurement device as shown in 3.3.1 didn't allow for a greater precision.

Aside from the remarks for (A) the median of TV answers were actually closest and had the lowest deviation. HMD is somewhere between TV and Real. For (B) Real tend to have the lowest deviation and the lowest spread. While the medians of all tests are somewhat close, the deviation of HMD is visibly higher when compared to the others. In (C) TV answers are again closest to the correct value with Real tests having the highest range. HMD is again placed in the middle between Real and TV. In (D) TV has the highest extend of answers while also maintaining a similar median as HMD. Here Real answers are nearest to the correct value and also have the lowest interval. Again HMD is somewhere in the middle between those two. (E) shows a similar picture to (D) with TV's spread being the highest, then HMD and Real having the lowest. Looking at the medians, TV and Real are closer together, while HMD has a visibly higher one.

In general it can be said that answers made during the real test are more accurate both in terms of median as well as it's range. Interestingly in four out of five cases HMD sits in the middle between Real and TV answers. The high amount of deviation for answers made in stop 4 and 5 can be attributed to participant's higher tendency to lose their bearing and therefore the location of the well. While this happened a few times during HMD and TV tests, no participant made similar remarks during real test.

The correlation matrix in contrast suggests HMD answers behave in a similar way like the TV answers as both have the same number of found matches and share a common positive link between the deviation at stop 4 and 5. However, Real has also a positive link between these two.
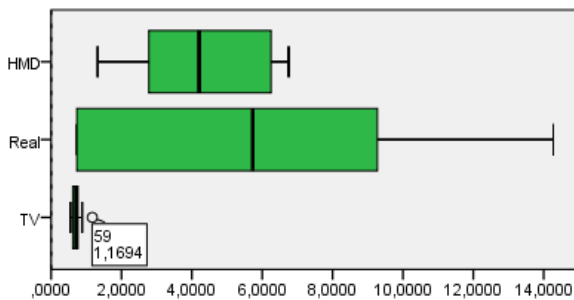
(a) Angular deviation at stop 1
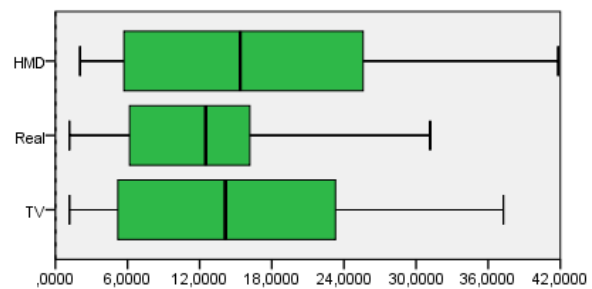
(b) Angular deviation at stop 2
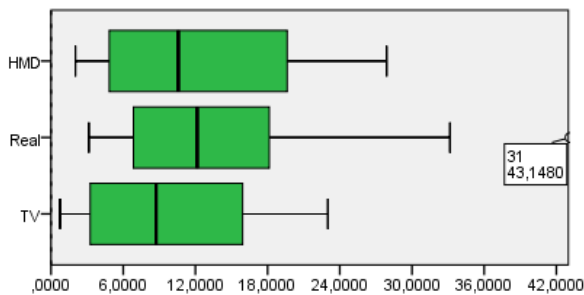
(c) Angular deviation at stop 3
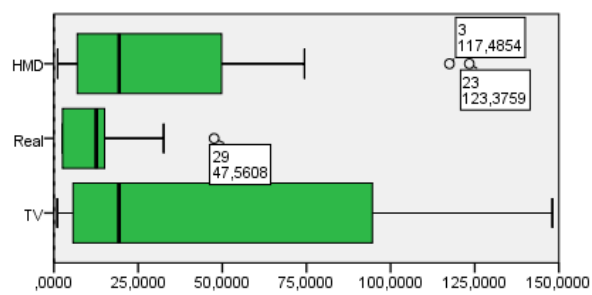
(d) Angular deviation at stop 4
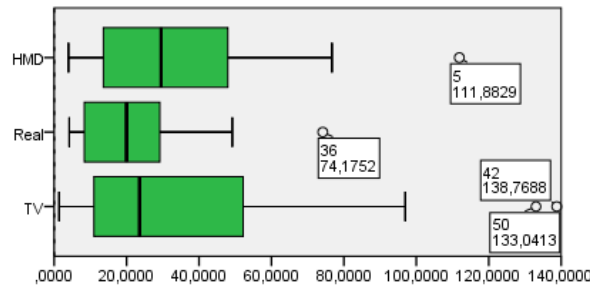
(e) Angular deviation at stop 5

Figure 3.14: Results of research question 1d as amount of deviation from target

			Angular deviation to well at Stop 1	Angular deviation to well at Stop 2	Angular deviation to well at Stop 3	Angular deviation to well at Stop 4	Angular deviation to well at Stop 5
Kendall-Tau-b	Angular deviation to well at Stop 1	Korrelationskoeffizient	1,000	,029	,248	-,067	,076
		Sig. (2-seitig)	.	,856	,116	,672	,629
		N	21	21	21	21	21
	Angular deviation to well at Stop 2	Korrelationskoeffizient	,029	1,000	,281	,152	,229
		Sig. (2-seitig)	,856	.	,067	,324	,135
		N	21	22	22	22	22
	Angular deviation to well at Stop 3	Korrelationskoeffizient	,248	,281	1,000	,177	,255
		Sig. (2-seitig)	,116	,067	.	,248	,096
		N	21	22	22	22	22
	Angular deviation to well at Stop 4	Korrelationskoeffizient	-,067	,152	,177	1,000	,316*
		Sig. (2-seitig)	,672	,324	,248	.	,040
		N	21	22	22	22	22
	Angular deviation to well at Stop 5	Korrelationskoeffizient	,076	,229	,255	,316*	1,000
		Sig. (2-seitig)	,629	,135	,096	,040	.
		N	21	22	22	22	22

(a) HMD

			Angular deviation to well at Stop 1	Angular deviation to well at Stop 2	Angular deviation to well at Stop 3	Angular deviation to well at Stop 4	Angular deviation to well at Stop 5
Kendall-Tau-b	Angular deviation to well at Stop 1	Korrelationskoeffizient	1,000	,291	,030	,151	,294
		Sig. (2-seitig)	.	,153	,886	,469	,152
		N	16	16	16	16	16
	Angular deviation to well at Stop 2	Korrelationskoeffizient	,291	1,000	,062	,073	,478*
		Sig. (2-seitig)	,153	.	,749	,711	,013
		N	16	16	16	16	16
	Angular deviation to well at Stop 3	Korrelationskoeffizient	,030	,062	1,000	,525**	,287
		Sig. (2-seitig)	,886	,749	.	,008	,142
		N	16	16	16	16	16
	Angular deviation to well at Stop 4	Korrelationskoeffizient	,151	,073	,525**	1,000	,459*
		Sig. (2-seitig)	,469	,711	,008	.	,020
		N	16	16	16	16	16
	Angular deviation to well at Stop 5	Korrelationskoeffizient	,294	,478*	,287	,459*	1,000
		Sig. (2-seitig)	,152	,013	,142	,020	.
		N	16	16	16	16	16

(b) Real

			Angular deviation to well at Stop 1	Angular deviation to well at Stop 2	Angular deviation to well at Stop 3	Angular deviation to well at Stop 4	Angular deviation to well at Stop 5
Kendall-Tau-b	Angular deviation to well at Stop 1	Korrelationskoeffizient	1,000	-,116	-,295	,158	,263
		Sig. (2-seitig)	.	,475	,069	,330	,105
		N	20	20	20	20	20
	Angular deviation to well at Stop 2	Korrelationskoeffizient	-,116	1,000	,316	,011	-,221
		Sig. (2-seitig)	,475	.	,052	,948	,173
		N	20	20	20	20	20
	Angular deviation to well at Stop 3	Korrelationskoeffizient	-,295	,316	1,000	-,105	-,042
		Sig. (2-seitig)	,069	,052	.	,516	,795
		N	20	20	20	20	20
	Angular deviation to well at Stop 4	Korrelationskoeffizient	,158	,011	-,105	1,000	,579**
		Sig. (2-seitig)	,330	,948	,516	.	,000
		N	20	20	20	20	20
	Angular deviation to well at Stop 5	Korrelationskoeffizient	,263	-,221	-,042	,579**	1,000
		Sig. (2-seitig)	,105	,173	,795	,000	.
		N	20	20	20	20	20

(c) TV

Figure 3.15: Correlations between the answers of research question 1d

3.4.2 Results for research question 2

As laid out in the previous parts 1.3 and 3.2 the second research question "How is the peripheral perception influenced?" was tested with two hypothesises. One of these comprises of survey questions, while the other one is based on printed out maps like in research question 1. Aside from Boxplots this questions also is visualised with pie charts.

Results for hypothesis RQ 2a The hypothesis "Peripheral perception is significantly different when asked about smaller objects recently encountered" is tested with six survey questions as displayed in figure 3.16. It's important to keep in mind that these questions were merged and coded based on text answers as mentioned in 3.4.
(A) shows a case where HMD strongly tends towards the Real as in both the majority answered correctly. TV in contrast has a large number of wrong answers.
The Boxplots (B) shows a somewhat common sight with HMD and TV being closely together and Real having a higher range of their answers.
(C) has again a case where HMD tends more towards the Real answers than towards the TV, regarding the number of correct answers. However, similar to TV, HMD had a higher variance of different answers than the Real counterpart and a higher number of participants who didn't know or saw the treebuckets.
Looking at the chart for (D), the Real tests had the highest portion of correct answers. Most answers in HMD and TV Test were at best only partially correct with a higher number of people who didn't know, which includes both wrong answers and "didn't see anything special".
(E) has multiple answers because the colour of the structure in question was hard to describe and somewhere between light red and red-brown. This becomes apparent as most of the Real answers stated red as the colour and most HMD and TV answers more leaning towards brown. This time HMD had the highest portion of participants who didn't know or didn't see the door frame.
(F) was probably the hardest question especially for the Real tests as the tunnel in this version of the fortress had a different symbol which confused some participants. Apart from this HMD has a higher portion of partially correct answers, while TV has one completely correct answer, but also the highest portion of people who didn't see a symbol.
Looking at the correlations table, there is only a single link in total found significant which is among HMD answers. The reason for this likely lies in the way the variables are coded as they used to be strings.
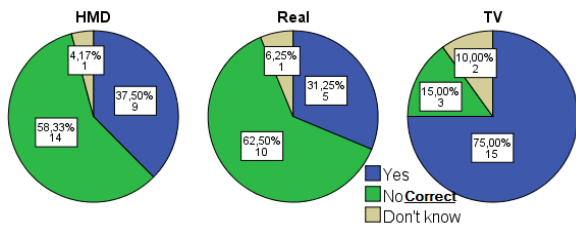
(a) Where there only planted trees in the main court?
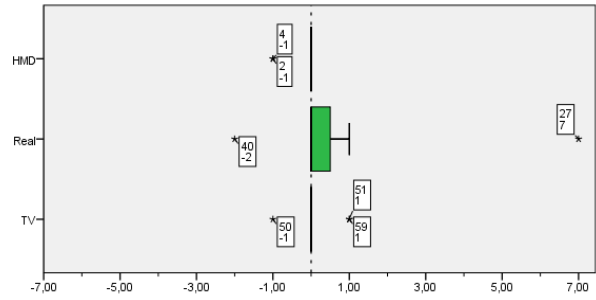
(b) How large where the sets of arrowslits on the kurtine wall?
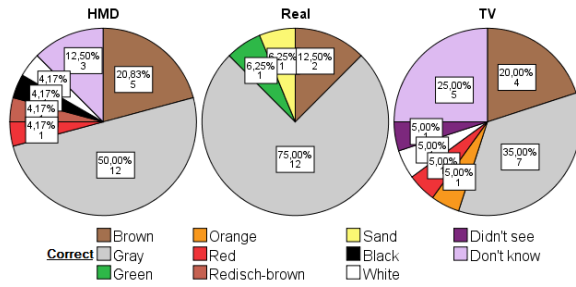
(c) What colour are the treebuckets?
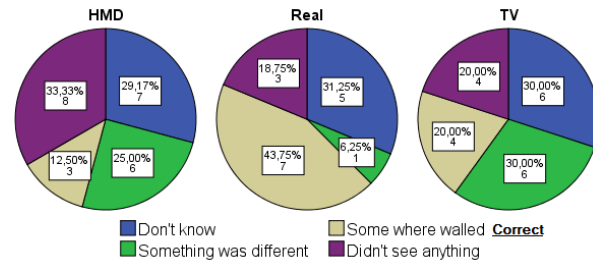
(d) Was there something special about the windows in the area over the tunnel?
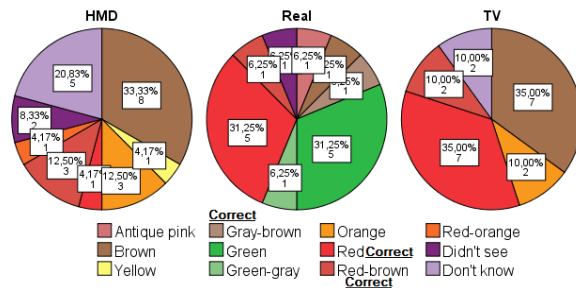
(e) What colour had the door frame of the 4 column wall?
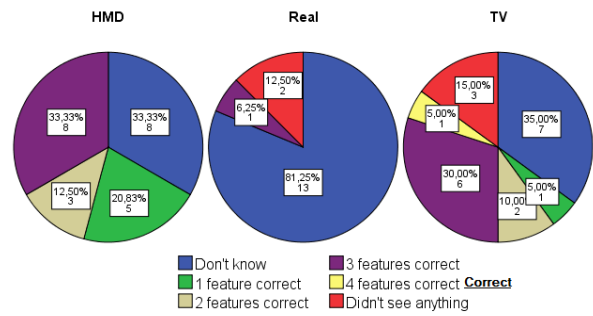
(f) What symbol was in the side tunnel?

Figure 3.16: Results of research question 2a

Kendall-Tau-b			Where there only planted trees in the main court?	How large where the sets of arrowslits on the kurtine wall? (Deviation)	What colour are the treebuckets?	Was there something special about the windows in the area over the tunnel?	What colour had the door frame of the 4 column wall?	What symbol was in the side tunnel?
	Where there only planted trees in the main court?	Korrelationskoeffizient	1,000	,247	,082	,215	-,005	,370*
		Sig. (2-seitig)	.	,228	,664	,253	,976	,050
		N	24	24	24	24	24	24
	How large where the sets of arrowslits on the kurtine wall? (Deviation)	Korrelationskoeffizient	,247	1,000	,043	-,219	,208	,000
		Sig. (2-seitig)	,228	.	,822	,253	,261	1,000
		N	24	24	24	24	24	24
	What colour are the treebuckets?	Korrelationskoeffizient	,082	,043	1,000	-,034	,056	-,099
		Sig. (2-seitig)	,664	,822	.	,845	,741	,575
		N	24	24	24	24	24	24
	Was there something special about the windows in the area over the tunnel?	Korrelationskoeffizient	,215	-,219	-,034	1,000	-,223	-,130
		Sig. (2-seitig)	,253	,253	,845	.	,191	,463
		N	24	24	24	24	24	24
	What colour had the door frame of the 4 column wall?	Korrelationskoeffizient	-,005	,208	,056	-,223	1,000	,178
		Sig. (2-seitig)	,976	,261	,741	,191	.	,297
		N	24	24	24	24	24	24
	What symbol was in the side tunnel?	Korrelationskoeffizient	,370*	,000	-,099	-,130	,178	1,000
		Sig. (2-seitig)	,050	1,000	,575	,463	,297	.
		N	24	24	24	24	24	24

(a) HMD

Kendall-Tau-b			Where there only planted trees in the main court?	How large where the sets of arrowslits on the kurtine wall? (Deviation)	What colour are the treebuckets?	Was there something special about the windows in the area over the tunnel?	What colour had the door frame of the 4 column wall?	What symbol was in the side tunnel?
	Where there only planted trees in the main court?	Korrelationskoeffizient	1,000	-,016	-,221	,187	,211	,019
		Sig. (2-seitig)	.	,948	,361	,426	,350	,937
		N	16	16	16	16	16	16
	How large where the sets of arrowslits on the kurtine wall? (Deviation)	Korrelationskoeffizient	-,016	1,000	,192	-,068	,114	-,179
		Sig. (2-seitig)	,948	.	,421	,767	,606	,462
		N	16	16	16	16	16	16
	What colour are the treebuckets?	Korrelationskoeffizient	-,221	,192	1,000	-,118	,069	,000
		Sig. (2-seitig)	,361	,421	.	,610	,758	1,000
		N	16	16	16	16	16	16
	Was there something special about the windows in the area over the tunnel?	Korrelationskoeffizient	,187	-,068	-,118	1,000	-,022	,337
		Sig. (2-seitig)	,426	,767	,610	.	,921	,154
		N	16	16	16	16	16	16
	What colour had the door frame of the 4 column wall?	Korrelationskoeffizient	,211	,114	,069	-,022	1,000	-,234
		Sig. (2-seitig)	,350	,606	,758	,921	.	,301
		N	16	16	16	16	16	16
	What symbol was in the side tunnel?	Korrelationskoeffizient	,019	-,179	,000	,337	-,234	1,000
		Sig. (2-seitig)	,937	,462	1,000	,154	,301	.
		N	16	16	16	16	16	16

(b) Real

Kendall-Tau-b			Where there only planted trees in the main court?	How large where the sets of arrowslits on the kurtine wall? (Deviation)	What colour are the treebuckets?	Was there something special about the windows in the area over the tunnel?	What colour had the door frame of the 4 column wall?	What symbol was in the side tunnel?
	Where there only planted trees in the main court?	Korrelationskoeffizient	1,000	,259	,269	,365	-,323	,118
		Sig. (2-seitig)	.	,237	,180	,074	,114	,560
		N	20	20	20	20	20	20
	How large where the sets of arrowslits on the kurtine wall? (Deviation)	Korrelationskoeffizient	,259	1,000	-,233	,079	-,137	,381
		Sig. (2-seitig)	,237	.	,252	,702	,508	,063
		N	20	20	20	20	20	20
	What colour are the treebuckets?	Korrelationskoeffizient	,269	-,233	1,000	,047	-,168	-,185
		Sig. (2-seitig)	,180	,252	.	,806	,377	,326
		N	20	20	20	20	20	20
	Was there something special about the windows in the area over the tunnel?	Korrelationskoeffizient	,365	,079	,047	1,000	-,253	,101
		Sig. (2-seitig)	,074	,702	,806	.	,190	,598
		N	20	20	20	20	20	20
	What colour had the door frame of the 4 column wall?	Korrelationskoeffizient	-,323	-,137	-,168	-,253	1,000	-,122
		Sig. (2-seitig)	,114	,508	,377	,190	.	,523
		N	20	20	20	20	20	20
	What symbol was in the side tunnel?	Korrelationskoeffizient	,118	,381	-,185	,101	-,122	1,000
		Sig. (2-seitig)	,560	,063	,326	,598	,523	.
		N	20	20	20	20	20	20

(c) TV

Figure 3.17: Correlations between the answers of research question 2a

Results for hypothesis RQ 2b   The hypothesis "Peripheral perception is significantly different when asked to locate larger objects encountered longer ago" was tested with the same printed out maps as hypothesis RQ 1c. Similar to those answers were turned into a heatmap with marker colour ranging from light turquoise to dark turquoise. The two asked structures are the well (X Marker) and a fence on the court yard (circled in) as displayed in 3.18. Of note for the latter is that there are multiple fences on the real fortress which were represented by the same fence model in the virtual model. However, a close look at the picture with the fence on it shows an unique background which can only be found at the correct location.

Comparing the answers regarding the well shows that HMD and TV participants put it often in the right place, while Real ones had more problems finding it. In regards to the fence Real answers are clearly converging on the correct location, while HMD and TV answers tend to get distracted by the other fences on the fortress. One is of particular note as it was used as a scale cue, but with a different structure in it's background. Looking closer, TV answers have an even higher tendency to be distracted than the HMD ones. Consulting the map reading rating, TV participants had seemingly less problems with the map and HMD is positioned in the middle between the two. The remaining two diagrams support this as in both TV participants are more confident than others. This stands in contrast to the findings of the findings in the drawn maps.
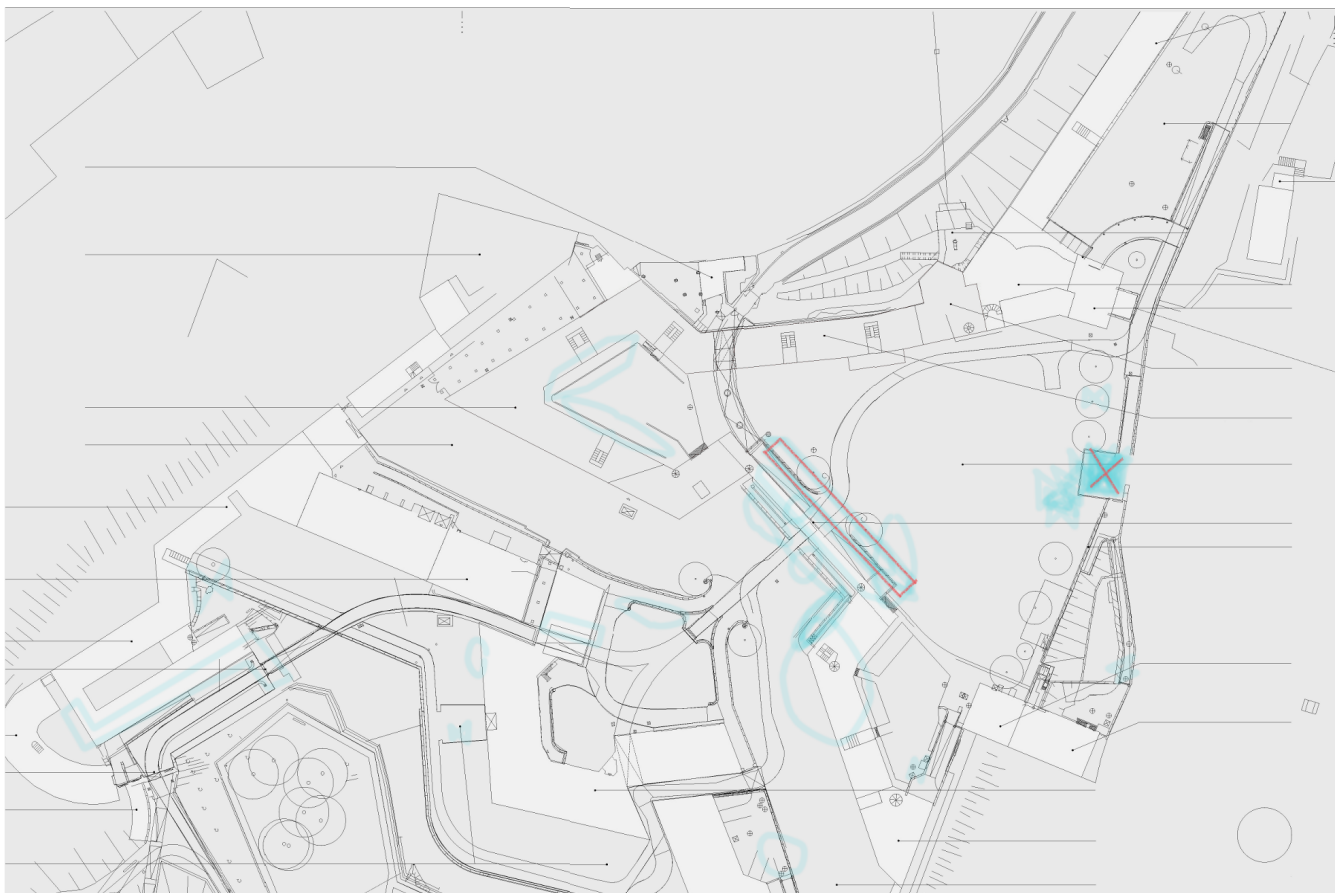
(a) HMD Well and Fence Location
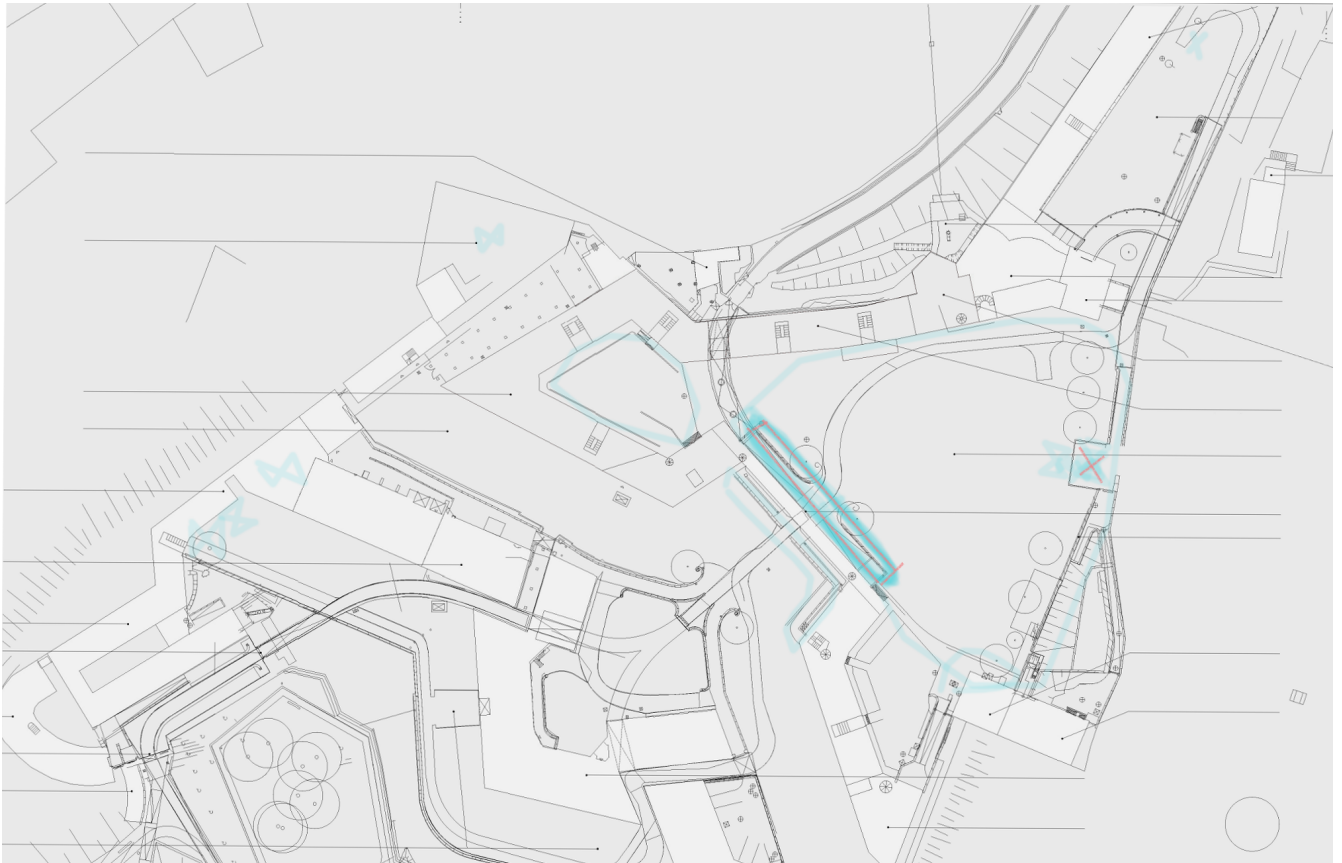
(b) Real Well and Fence Location
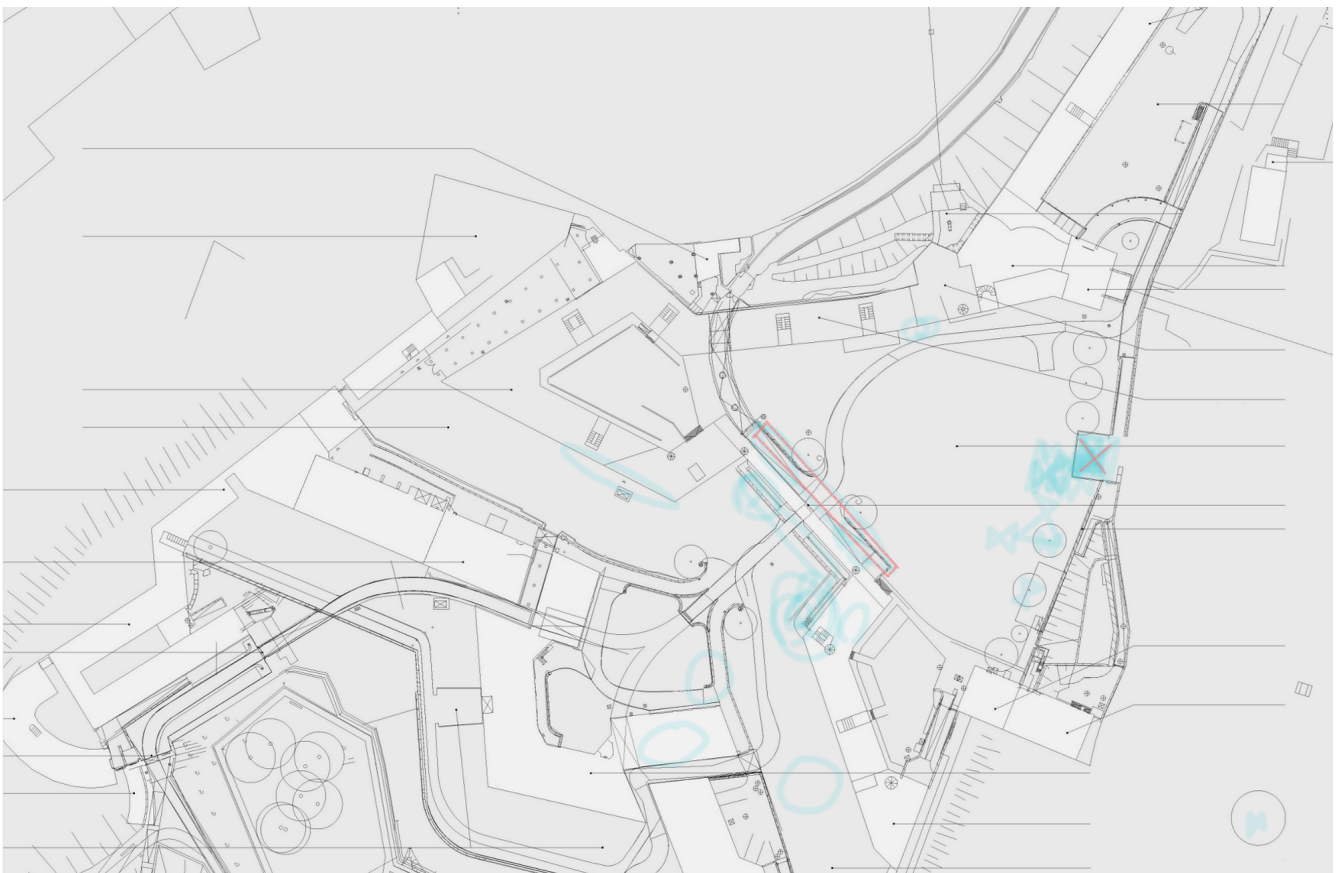
(c) TV Well and Fence Location

Figure 3.18: Results of research question 2b as Heatmaps

(a) Map reading rating

(b) Own map reading assesment

(c) Map reading assesment based on child
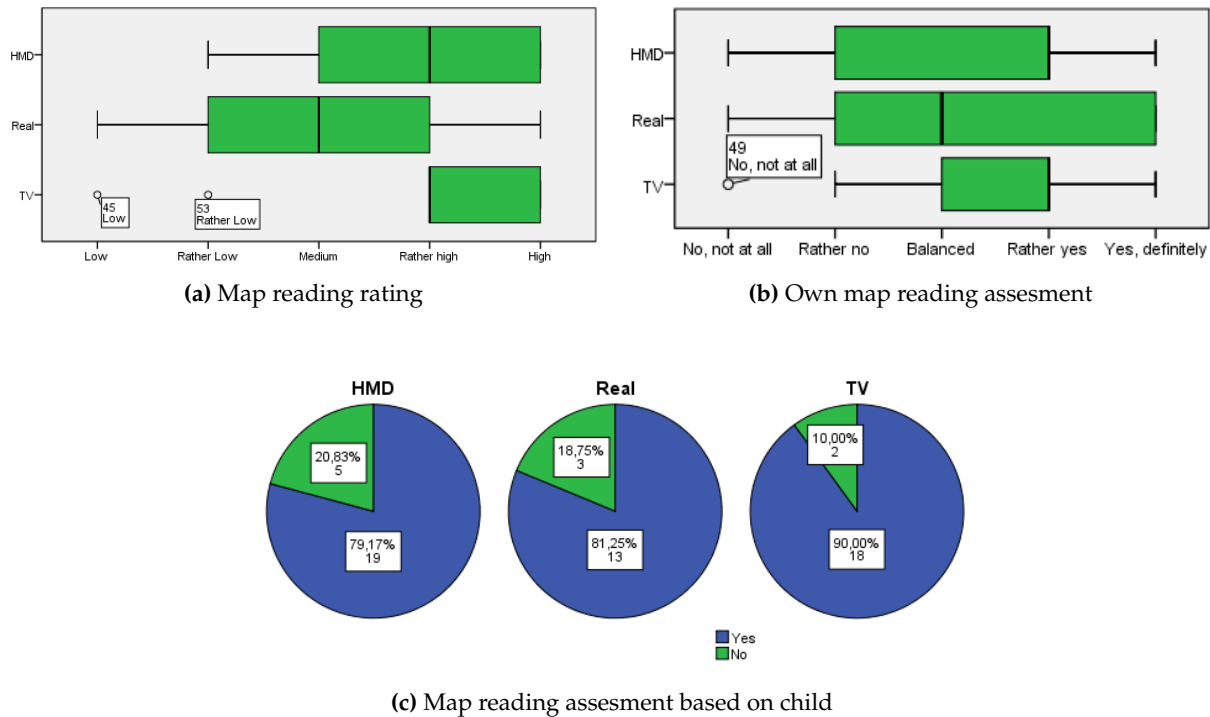
Figure 3.19: Additional data regarding the map reading skills

3.4.3   Results for research question 3

As mentioned in previous parts 1.3 and 3.2 the third research question "What influence has prior experience?" was split into two variants of prior experience with each being tested with three hypothesises. The two sets of preconditions were tested with seven to nine survey questions, while the postconditions were tested with survey questions from previous parts. From the three demographic questions that were intended to supplement this analysis only two were included as the distribution of gender varied significantly between the experiment types. Postconditions continue to be interpreted as deviation from the actual value. These were then combined according to the hypothesis and analysed with a correlation matrix similar to the ones in previous sections. Because the resulting matrices are quite large, they can be found in the appendix with some being cut down to only show the relevant columns. Only significant correlations will be discussed in the next parts.

Results for hypothesis RQ 3a   The hypothesis "Prior real experiences significantly influences 2D distance judging" was tested with seven questions exploring the relevant prior real experiences as well as three demographic variables combined together with the four distance judging questions from hypothesis RQ 1a.
Looking at the tables reveals little. The only significant relations are inside the pre or post conditions, but only one can be found across them. This one negatively relates the age at which participants started going alone to regular places with the width of the tunnel.

Results for hypothesis RQ 3b   The hypothesis "Prior real experiences significantly influences 3D Space judging" had the same ten survey questions as preconditions, but this time the eight size judging questions from RQ 1b as postconditions.
Going over the tables, uncovers only one significant correlation for HMD and TV both of them related to the height of the participant. HMD relates this positively to the height of the last wall, while TV relates it negatively and very significantly to the height of the tree in front of

the tunnel. However, some can be found in Real. There is a positive correlation in well height deviation and membership in boy scouts, a positive correlation in width of kurtine and mode of transport after drivers license and a very significant negative one between height of the four column wall and age at which participants started going alone to irregular places. Furthermore, it's the only environment in which correlations between number of fortress visits in the last four years can be found. One of them is positively related to the tree height and the other one is negatively related to the height of the opposing wall.

Results for hypothesis RQ 3c   The hypothesis "Prior real experiences significantly influences peripheral perception" had also the same survey questions as preconditions, but this time it used the six peripheral perception questions from RQ 2a as postconditions. It's important to keep in mind that most of the postconditions are strings recoded to numerical values in order to be able to use the correlations algorithm.

Examining the tables, shows a number of correlations especially for HMD Tests. There are five significant relations in total, one of which is very significant. The ones found are between colour of treebuckets and age at which participants started going alone to regular places, anything special with the windows and age at which participants started going alone to irregular places as well as mode of transport before drivers license, which symbol was displayed in side tunnel and which kind of city participants spend of their childhood, which mode of transport they used before drivers license.

Moving over to correlations found in Real answers there are two, one of which is very significant. It relates the colour of tree buckets with age at which participants started going alone to irregular places. The other one is between colour of door frame and mode of transport before drivers license.

Finally, there were three correlations found in the TV answers. They are between the kind of trees on the courtyard and which mode of transport they used before drivers license, which colour the door frame was and which mode of transport they used before drivers license as well as which symbol was visible in the side tunnel and age at which participants started going alone to regular places.

Results for hypothesis RQ 3d   The Hypothesis "Prior gaming experiences significantly influences 2D distance judging" had eight survey questions in relation to prior virtual experiences as well as one demographic question as precondition and the four distance judging questions from hypothesis RQ 1a as postcondition. Some of the preconditions are based on strings again, which voids an interpretation of the correlation coefficient. It's important to keep in mind that "what is your favourite video game genre" had to be split into it's possible answers which increase the number of cells. Also during the analysis SPSS encountered a random problem which prevented it from printing out correlations related to not having a preference in genre, but only in the TV answers. As the reason for this couldn't be found it was assumed that there are no significant correlations in the affected variable.

Considering the tables, shows some correlations without any being very significant. HMD has three links which relate a favourite video game genre (No Preferences, Adventure, Action) to distance between floor lights, height of the tunnel and to the width of the path towards the tunnel respectively.

Among the Real answers two correlate in a significant way. They again have a favourite genre (Action-Adventure and Strategy) as precondition, but this time the height of the tunnel as the same postcondition.

There were no significant relations found within the TV answers.

Results for hypothesis RQ 3e   The Hypothesis "Prior gaming experiences significantly influences 3D Space judging" had the same nine survey questions as preconditions, but uses the

eight size judging questions from hypothesis RQ 1b as postconditions.

As this combination of variables introduces a large number of possible matches the number of actual matches increases as well. This leads to HMD having ten significant correlations of which one is very significant. Two of these relate a favourite genre (Action-Adventure) to the height of the tree in front of the tunnel and height of the opposite wall. The very significant one is between favourite game and width of arrow slits wall. Two of them are in relation to the game participants spend the most time with and width of arrow slits wall and width of the four column wall respectively. A negative one is between the number of days participants used to spend on playing video games and height of the same four column wall. The next one negatively relates the estimation of the well height with the amount of time recently spend on video games. The last two are based on if the participant had already tested an HMD and relate this to the height of the tree in front of the tunnel and the height of the four column wall. The last one relates course of study with the width of a wall.

The number of matches are lower in the Real answerset with 4 normal ones. Two of these relate favourite genres (action-adventure and Strategy) to the estimated height of the well. Another positively relates the time currently spend playing video games with the height of the last wall. The final one negatively relates the number of video games played with the width of the arrow slits wall.

The number of matches for TV exceeds the number of HMD with a total of twelve of which two are very significant. Interestingly to see is that eight of these are related to the height of the opposite wall with one of them being very significant and most of them negative. The answer to this question relates to three different favourite genres (Action-Adventure, Role Playing Game and No Preference), the amount of days spent playing video games currently and during school days as well as the number of hours spend with games recently and the number of games played in the last year (very significant). Four are a positive one between width of four column wall and type of childhood city, width of arrow slits wall and no preference in favourite genre, height of four column wall and game genre with the most time spend and finally a very significant one between width of arrow slits wall and if they tried HMD out before. The final one is related to course of study.

Results for hypothesis RQ 3f   The hypothesis "Prior gaming experiences significantly influences peripheral perception" used the six peripheral questions from hypothesis RQ 2a as postconditions.

Similar to hypothesis RQ 3c, HMD answers show the most correlations with the respective prior experiences with six of which one is very significant. The first two are between a favourite genre (strategy) and the kind of trees on the courtyard respective the symbol in the side tunnel. The next one is between group size of arrow slits and game genre with most time spent. The significant one is between the colour of the tree buckets and a favourite genre (simulation). Another one is between the group size of the arrow slits and the game genre with the most time spent. The last two are between the colour of the tree buckets and the number of days and number of hours a participant currently plays video games.

Moving over to the Real answers there are four significant relations. Two of those link the colour of the tree buckets with the number of days and number of hours a participant used to play video games during school days. The other two are between the number of days a participant plays games currently and the kind of trees on the courtyard as well as a positive one between the group size of the arrow slits and the number of video games played.

This paragraph is completed by looking at the three correlations of TV answers with one being very significant. The two less significant are between the features of the windows and the number of days a participant used to play as well as his/her number of games played. The very significant links is with the side tunnel symbol and if they tried out an HMD previously.

3.4.4   Results for research question 4

As mentioned in the previous parts 1.3 and 3.2 the forth and final research question "How does the emotional response change?" was tested with two hypothesises. These were tested with three or four survey questions and are visualised with the help of Boxplots in the following paragraphs. As mentioned in the section about survey design these are formulated in an indirect way and use a five point Likert scale to improve the quality of answers.

Results for hypothesis RQ 4a   The hypothesis "The perception of positive emotions is significantly different in different realities" was tested with four survey questions.
Looking at (A), Real participants liked the visit the most, while their TV counterparts didn't like it as much. HMD is again in the middle between the two. While it shares the same median as TV, the range of answers tends to be smaller just like with Real.
(B) shows a similar picture as Real answers were mainly positive with TV being more sceptical though they all share the same median. Whereas this is true for HMD based tests as well the range of answers is wider, but without the more sceptical answers as TV. Note that this question always asked for the participants opinion on his version of the fortress.
In (C) HMD has the highest amount of positive answers even before Real, while also having some negative outliers. TV participants are reserved, but still agreeing with a number of outliers point rather towards a more positive general consensus.
In the last Boxplot (D) HMD and TV match in every characteristic and show a balanced opinion across the scale. A thing to keep in mind is the way this question is formulated to check participants expectations. Real answers showed a higher amount of surprise which doesn't necessarily mean they had a good impression.

In general all participants seemed to have liked the tests. In half the cases HMD is in the middle between Real (most enjoyed) and TV (less enjoyed). (C) is a bit peculiar as HMD participants actually enjoying it more than Real ones albeit by not much. (D) is also of note as well as HMD and TV answers match up exactly.
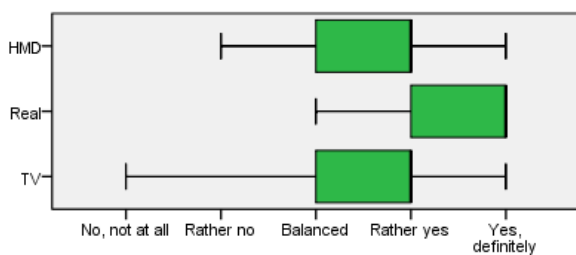
(a) Would you recommend a visit to a close friend?
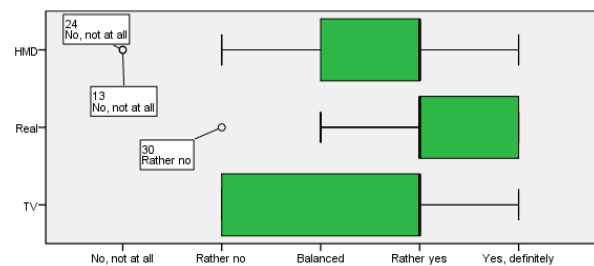
(b) Is it worth a trip with your business colleagues or class mates?
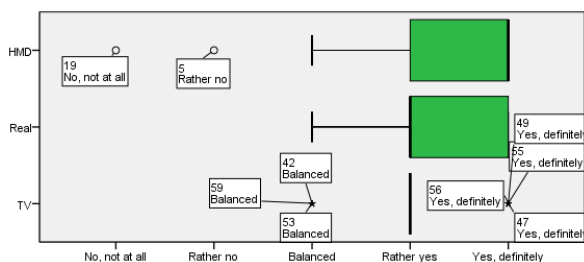
(c) Are you interested in exploring the rest of the afterwards fortress?
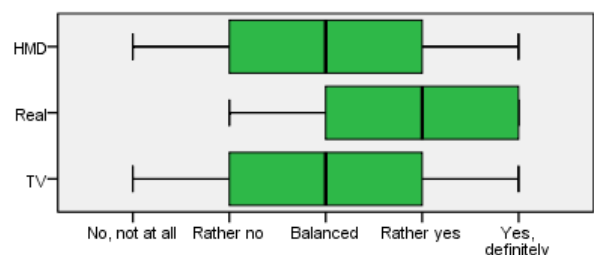
(d) Did you expect the fortress to have so many details?

Figure 3.20: Results of research question 4a

Results for hypothesis RQ 4b   The hypothesis "The perception of negative emotions is significantly different in different realities" was tested with four survey questions. Note these questions although looking into the opposite spectrum of emotions than the previous hypothesis still use the same scale.

(A) shows a rare case where Real and TV match up, both in terms of median as well as range of answers. While the HMD users agreed more, there are also some negative outliers among them.

(B) is a case which shows the pitfalls of using the same scale across all questions. As this question is formulated in a negative way, negative answers actually equal participants who liked the test. Real participants were irritated by the size of the fortress the least, while TV users found it more of a problem. This affects only the range of answers as they all have the same median. HMD user answers again show characteristics of both sides.

The Boxplot (C) shows a similar picture to (A) as HMD answers are more agreeing than Real ones. TV answers differ more to the negative side of not begin effected, while still having the same median as Real.

The last chart (D) confirms a common problem with HMDs that their use can lead to motion sickness, while virtually none of the TV users had problems in this regard.

The trend observed in the previous hypothesis seems to continue here as well. Most liked the test and weren't bothered too much by it's length. Comparing the Plots (A) and (C) both have cases where HMD testers were influenced the most even before Real world ones which is a rare sight among all hypothesises.
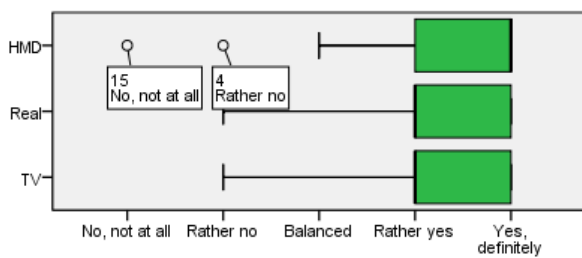
(a) Do you think time flew by while doing the test?
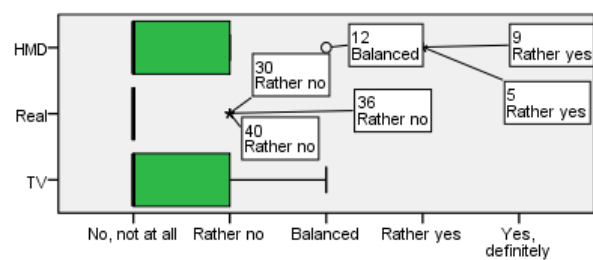
(b) Does it bother/irritate you how big the fortress is?
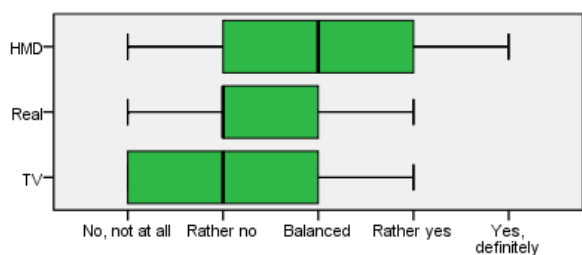
(c) Do you think 1st / 2nd Grade school children (6-8) would be scared of the tunnel?
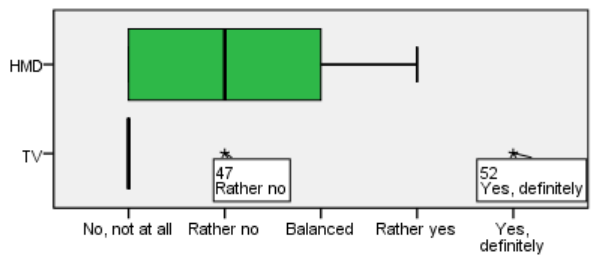
(d) Are you feeling motion sick?

Figure 3.21: Results of research question 4b

Chapter 4

Conclusion

In this final chapter the findings of the data evaluation are interpreted and insights are formulated. Moreover, an outlook into further research opportunities is given which is concluded by a summary.

4.1 Interpretation of results

As the main goal of this thesis and the basis for the research questions is to find clues if the HMD experience is closer to the one made on a traditional TV or closer to real life, there won't (and can't because of the low sample size) be a lengthy search for correlations or what answers predict which outcomes. Instead the focus lies more on the search for promising aspects that can be explored in further research with larger sample sets.

4.1.1 Research question 1

The analysis made in 3.4.1 for the first research question "How does the spatial Perception change based on the current reality?" found some interesting points.
For the estimation of distances as reviewed with the two hypothesises "The error in estimating is significantly different when judging distances" and "The error in estimating is significantly different when judging the size of a room/area" there seems to be a reoccurring pattern in the distribution of answers.
Firstly, in the majority of cases across all test participants underestimated the size of objects. While a tendency to over/underestimate could be somewhat expected from the HMD and TV tests, it's interesting to notice the same phenomenon in the real test as well, albeit not as strong. Because this affected all tests, the reasons don't seem to be based on problems of the virtual model such as scale and inaccurate representations, but rather on a general phenomenon where humans underestimate distances and dimensions.

Insight 1. *The human tendency to underestimate distances and dimensions in 3 dimensional space is maintained in virtual worlds viewed via a HMD.*

Secondly, in quite a few instances answers made during the Real tests and those made during TV tests are opposing each other in terms of median value, the distance from the median to the correct value and the range of answers. However, no one is always closer or more precise in its answers. In these cases, the characteristics of HMD answers are somewhere in the middle with a leaning towards the TV. This implies that even though HMD and TV used the exact same virtual model it still makes a difference in regards to judging distances.
Looking at the correlations found, HMD differs from both Real and TV tests. While the number of links found is closer to TV especially in regards to the former hypothesis, they are not with the same correlations. It also shares links with Real answers. A significant pattern, if HMD usage has a higher influences on height or width estimations couldn't be found, but there seems

to be a tendency towards height estimations.

Insight 2. *Experiencing a virtual world through a HMD has an influence on the estimation of distances and dimensions.*

When looking at the analysis of the next hypothesis "The error in estimating is significantly different when judging the walked distance", it's important to keep in mind that the number of participants varies between tests with HMD having the most and Real the least. This could be the reason for the seemingly lower number of outliers during Real test. Interesting to see is that the HMD answers are more focused in all three main areas, while having less or as much as outliers than TV. This still holds up compared to the real answers, while discounting for the different number of participants. Reasons for this could lie in two effects. First one of the main differences between a HMD and a TV is the feeling of presence and being "inside" the world as opposing to "in front of a window" to it. This combined with the reduced distraction from different sources like in the reality with other people and the environment itself, may explain why the answers have the highest accuracy. This is contrasted by the additional data regarding the map reading abilities which put HMD users more towards the real ones by being less confident than TV users.

Insight 3. *Matching virtual world structures to a map is improved by experiencing it through a HMD as compared to using a TV.*

Looking at analysis of the last hypothesis "The error in estimating is significantly different when judging the angular position of points", some noteworthy details can be observed. As mentioned some participants during HMD and especially TV test lost the position at stop 4 (inside the tunnel) or stop 5 (last and furthest away from well). Interestingly enough these were the selected barrier points which matches their definition. This didn't happen during Real tests. One reason could be again the feeling of presence inside the virtual world with little influences from the outside one which kept participants from losing the position of the well to much. Another interesting fact is that similar to the first hypothesis HMD answers tend to be in the middle between Real and TV, again both in terms of median and range of answers.
The correlations table confirms the idea of TV participants in particular getting lost at the stop 4 or 5 as there is a positive link between those two. This means if someone guessed a higher value at stop 4 eg. is unsure where the well is, this will increase the deviation at stop 5 further. HMD was affected by this as well, but less significant and with a lower correlation value. This suggests that HMD users got lost, though not as much as TV users.

Insight 4. *Keeping track of virtual world objects is improved by using a HMD when compared to a TV*

4.1.2 Research question 2

The analysis made in 3.4.2 raised some noteworthy points primarily regarding the first hypothesis.
There seems to be a difference when looking at the peripheral perception of static features as HMD and TV not always match up. This is especially visible in survey questions (A) and (C) as the HMD clearly tends more towards Real than TV when asked about details related to trees. A possible explanation could be that participants in the HMD tests perceived the trees as part of the world and as something one would expect to be there. TV participants in contrast might viewed it just as a decoration which can be in a virtual space, but doesn't have to be there.
The results of (B) in regards to the arrow slits could point towards HMD and TV participants being less distracted by other influences as might have happened in the real world. However, when looking at (D) real participants generally fared better than those of HMD and TV. Note that both of windows there inside a wall and the respective wall were part of another survey question. This puts HMD more towards an opposite of Real as it's answers for (D) were more

inaccurate than the ones given during the TV test.

Looking at (E) and (C) under the aspects of colour perception, an interesting difference can be observed in HMD Tests. While in (C) HMD was closer to Real in terms to correct answers, but closer to TV in terms of range of answers, the same is not true in (E). Here HMD and Real have a higher range of answers, while TV has visibly fewer. This can also be found in the raw survey data, so a different approach to merging the answers to increase distinctiveness can be ruled out as a reason. Moreover, HMD participants had the most trouble answering as the portion of "didn't see" or "don't know" is highest here. This gives a hint to why HMD has a higher range of answers: the participants who did answer were probably not sure as they hadn't seen this detail.

Finally, the analysis of (F) already pointed out some problems with the tunnel model which could be the reason why the majority of real participants didn't know an answer to the question. Nevertheless, it's intriguing to see that HMD and TV visibly differ as all participants were inside the same tunnel. While around 50% of TV answers have got one or more features correct, this number increases to 70 % in HMD. This might again be attributed to a greater feeling of presence.

Due to the way the variables are coded, there is no additional insight available based on the correlation matrix.

Finding a pattern in the second hypothesis is not as clear. In regards to locating the well HMD matches up more with TV as the majority of participants put it in the right location. However, in regards to the fence, HMD sits more in the middle between Real and TV as answers weren't distracted as much by other fences with the same model. This implies that HMD users perceived the world a bit more detailed as they noticed the difference in background better. In summary HMD with it's higher perception of detail is situated in the middle between Real and TV.

Insight 5. *Using an HMD has a beneficial influence on peripheral perception which seems particularly present for larger objects such as trees.*

4.1.3   Research question 3

As the analysis made in 3.4.3 was split in two it seems sensible to split the interpretation in two as well and sum it all up in a last paragraph. When looking into positive or negative correlations, it's important to keep in mind that some conditions were based on strings recoded to numbers. As these don't follow a particular order there is not much to be gained in interpreting the algebraic sign.

Correlations found with prior real experiences as preconditions were sparse. One Hypothesis (influence on distance judging) only had a negative one. While the next one (influence on size judging) had more with two being very significant, most of them occurred in Real tests. This makes somewhat sense as having some prior Real experiences would indeed improve the estimation results in the real world. This is further indicated based on two links between number of past visits. HMD and TV only got one link each, both related to the height of the participant and height estimation. Having a link between ones body height and height estimation of objects seems obvious. However, while the HMD one is positive the TV one is negative. An interpretation of this would have needed both of them having the same algebraic sign. The final hypothesis in this subset found more correlations than the previous two combined with HMD having the most and Real the least, albeit with a very significant one. Interesting is also the multiple links between the symbol in the side tunnel or if something was special about the windows. This is interesting as it implies a relationship of having prior real knowledge with the peripheral perception in the virtual world which is not as strong in the real one.

The number of correlations related to prior virtual experiences was larger than in the set before. For the first hypothesis with the lowest number of matches the correlations had always something to do with the favourite genre of the participants across HMD and Real. Yet, in each

case the genre was different, but in three of the five cases the estimation of the tunnel height was affected. One could argue that height estimation plays an important role in navigating a virtual game environment. Nevertheless, as two (adventure and strategy) of the three genres generally don't have much to do with path finding in an extensive world, this idea can't be backed up. For this hypothesis HMD tends more to Real than TV.

Moving over to the second hypothesis which by far has the highest number of found correlations. Interesting in the HMD portion are two correlations around past HMD experiences and two different height estimations. Sadly, one is positive and the other negative and past HMD experiences is string based. A similar case can be found in regards to the favourite genre being Action-Adventure and two different height estimations, though a positive one is cancelled out by a negative one. In the Real answers are again correlations between a height estimation and the favourite genre strategy as previously observed, but with no immediate explanation. HMD and TV both have instances where different types of estimation are linked to the time spent during school days. Both of these are negative which would imply playing video games in the past makes creates a tendency to underestimate sizes. As there are only two cases, this can't be fully proven. Of special note is the high number of links found in TV Test in regards to the height of a wall. Three of them are linked to genres which had up till here no significance in other correlations. The others are based on game time primary recent. Again this was not observed before as past game time seems to be more important. Of the three very significant ones, two don't make sense as they link having a favourite game to improvements in width estimation and having tried out a HMD before with a hight estimation while in the TV tests. The last one is among the set of multiple correlations in TV, regarding the height of the wall. This relates the number of games played to the height which again hasn't much interpretability. All in all, despite the unusually high number of dependencies found no particular ones could be interpreted. HMD tends more towards TV with both having a high number of found matches. Concluding with the interpretation by looking at the analysis of the third hypothesis. HMD has the highest count of links found just as in the similar hypothesis RQ 3c. As seen in previous paragraphs the favourite genre strategy triggers correlations. This time it's with the kind of tree planted and the symbol in the side tunnel, both of which are positive. A possible interpretation could be that strategy games often require players to manage large amount of units on virtual map which requires and trains the attention to detail of said player. This could apply in the HMD as well as these are details in the world as well. Real has two interesting matches. Here the symbol in the sidetunnel is related to the time spent in videogames during school both of which are negative. As the former is ordered by increasing number of correct features it would imply having played more video games actually has a negative effect in this case. Moving over to TV there are two matches related to telling if something was special about the windows, both sharing the same negative algebraic sign. Yet, the two pre conditions are somewhat opposite of each other as one focuses on the past amount of days spent with games and the other with the current number of played games. Also this variable doesn't follow a particular order as the previous one. The two very significant ones are again not especially interesting. One is related to prior HMD use which doesn't make sense in the TV tests. The remaining one is related to a favourite genre (simulation) and the colour of the tree buckets. Nevertheless, this is the genre's first match so it's hard to pin down a pattern. In contrast to RQ 3c HMD tends to Real for this question.

Concluding the interpretation of this research questions is not straightforward. The influence of prior experiences on the distance judging is low and no variables particularly determined the outcomes. Which is odd as it could be expected to have in an impact at least in the corresponding realities. However, it might somehow be related to the different sense of scale in the virtual environments and the vast selection of games for which it's hard to pin down a single genre for. It was also surprising to not find evidence of links between a certain genres and spatial abilities. For example looking at games of the Role Playing Genre and the MMO like Bethesda's Skyrim or Blizzard's World of Warcraft: they sport spacious world with many places to visit and a lot of different routes to take. During one pre test a discussion was held

speaking about these relations and one participants reported an actual real world increase in her own path finding abilities by playing these games. Which makes sense as this is a common task in both realities.

Insight 6. *There is no correlation between any prior experiences and the distance judging.*

The effect on estimating the size of objects seems larger and more tailored for the corresponding reality as prior Real showed some significance in the Real tests. The same is true for the virtual test, but not across the realities. Nevertheless, interpreting the found matches again didn't reveal a set of influencing variables and in one instance the TV table was a bit disconnected from the others.

Insight 7. *There is limited evidence for a correlation between prior experiences and the estimation of sizes, but only in the corresponding reality.*

Lastly, an effect on peripheral perception is particularly noticeable for HMD as in both cases it got the highest number of links found. This is interesting as RQ 2a already showed a difference in peripheral perception between HMD and TV. Yet, as this effect is present across the realities it's hard to point out if the source for this is based on prior experiences or the general HMD characteristics.

Insight 8. *There is a correlation between peripheral perception and prior experiences while using a HMD.*

4.1.4 Research question 4

The analysis made in 3.4.4 found some interesting cases regarding the influence HMD has on the emotions of the participants. To better understand this it's important to recall which questions are mapped to which emotions according to Plutchik model as stated in 3.2.
In general participants had fun taking part in the test, with the Real tests being the most enjoyed ones and TV being the least one, albeit still positive. Most of the time HMD is placed in the middle between the two without a common tendency to one or the other. This is interesting as there were some participants who had problems with motion sickness, which would imply that they enjoyed it less. In some cases it was the HMD users who seemed to be effected the most and even more than in real life. This applies to positive as well as negative emotions alike. Examples for this are the emotions interest and fear. Of note for the first is that it was the only emotion with two survey questions and that they don't match up. The reason for this may lay in the way the question was posed as some participants had trouble understanding (B). In regards to the high influence on fear the reason could be again the higher feeling of presence as in the HMD the participant could only see the virtual world. In contrast to this TV users could easily see the real world by just turning around.

Insight 9. *HMD has an influence on selected emotions which is sometimes stronger than in the real world*

4.2 Outlook

The outlook is best discussed in two parts to focus on further research directions and technical progress.

Further Research Based on the findings there are a few interesting points for future consideration. First of all it would certainly improve the overall clarity of the findings by repeating them with a higher number of subjects. While 20 might be enough to find basic links, a higher

number such as 50 would certainly uncover additional insights or improve the found ones. A successor experiment could also benefit from availability of improved headset as the currently used one is already two years old. This timespan might not seems much, but with the rapid pace of technological progress newer and better alternative are already available. The promises here is that a higher resolution and higher refresh rate could improve the perception of the virtual world. Furthermore, a number of competitors introduced a larger choice of headsets to the market. One particular interesting feature is positional tracking over a larger area. This makes it possible to substitute the gamepad for a more direct input device such as gesture control. Based on these two changes an even larger area of research opens up. Regarding the findings of this study the emotional and peripheral perception sound like promising candidates for further investigation. While the former has already been research on in smaller context, there is not much evidence on how it is influenced by a HMD based virtual world on a larger scope. The peripheral perception in contrast didn't had much prior research to begin with. Yet, it is still part of the perception of a virtual world. Especially as they become more detailed it would certainly be interesting to see if the finding hold up.

Technical Trends   Looking at the technical progress made during the time this study was created, a trend can be observed. As evident by the current and planned releases now that the teething problems are largely solved manufactures focus on increase the specifications of their headsets. This particularly shows regarding the resolution and refresh rate of the display, but also to a lesser degree the field of view. Yet, this trend is limited by the computing power of current GPUs to the extend of which graphical fidelity needs to be decreased to met the resolution and frame rate targets [1]. Luckily, this limitations don't go as far as during the 90s where the high expectations of consumers weren't met in any form by available hardware. Based on own experience it can be said that the current technology is already very convincing and the number of shortcomings is constantly decreasing. On the other hand the currently available software is rather limited and a majority of it is still in development with early releases accessible. An example for this is video games. Many factors contribute to an enjoyable game with graphical fidelity being only one of them. Other ones are breadth and depth of the narrative as well as the game mechanics and interaction possibility with the virtual world. While the latter has some interesting concepts based on positional, head and gesture track or a combination of those, the former is often reduced to minimal or generic stories. This might change in the future as developers of all sizes find ways to apply old approaches to this new environment or come up with entirely new concepts. Another trend is develop the games and application directly inside VR to prevent problems with visual perception, as encountered in this study , and to better use the possible interaction methods [2].

As with any improvements at some points diminishing returns are to be expected. Some companies research where this point is, what displays are needed and how much computing power it would require. One research of note is from CPU and GPU manufacturer Advanced Micro Devices, Inc.[27]. According to this it would need a total of 116 megapixels (eg. using 16K 15.360*8640 pixel displays) combined with a larger field of view of 200 degrees horizontal and 135 degrees vertical all displayed at around 200hz to equal the human visual perception. To put this into perspective headsets like the Oculus Rift or HTC Vive have a resolution of around 2.5 Megapixels (2160*1200) with refresh rates of 90hz and viewing angles of around 100 degree. To further show the current limitations, one of the most powerful single GPUs on the market, the Nvidia GeForce GTX Titan X, can achieve around 30 to 50 frames per second on 8 Megapixel displays (3840*2160) in high fidelity video games [3]. Reaching these goals will certainly take some time both for display as well as for computing hardware manufactures.

---

[1] www.tomshardware.com/news/palmer-luckey-interview-gamescom-2015,29803.html, last access 17.04.16

[2] www.youtube.com/watch?v=JKO9fEjNiio, last access 19.04.16

[3] www.anandtech.com/show/9059/the-nvidia-geforce-gtx-titan-x-review, last access 17.04.16

Another factor that can be improved is ergonomics. While there have been improves in the recent years, current headsets tend to be bulky and heavy, which has an influence on prolonged use. This is partly due to the usage of LCD displays with LED backlights and one lens per eye. A new development in this regard are light field displays as describe by Lanman [28]. They are based on small and lightweight self luminance organic LED displays which use a microarray of fresnel lenses for focus. The prototype he build is also only based currently available of the self hardware. As show in figure 4.1 this results in a very compact HMD while still creating the illusion of depth. This approach is mainly limited by the already mentioned computing power restrictions and the displays, as they themself are a rather new development. This might slow down research into this promising aspect.
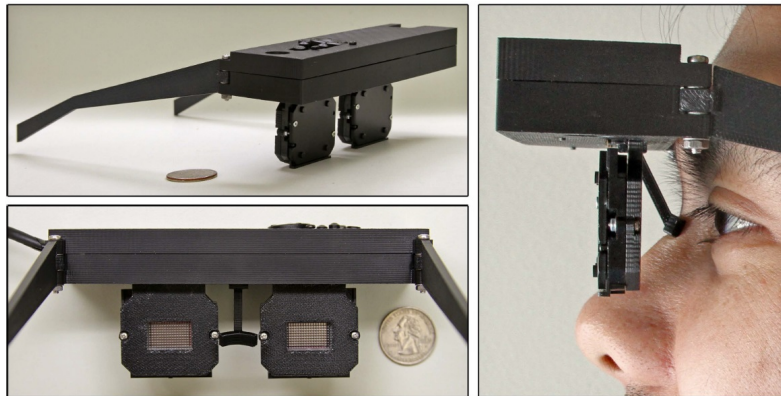
Figure 4.1: A highly compact light field display based HMD

4.3 Summary

While some of the areas have been researched previously, this study contributes a more broad look at the influence HMD based VR has on humans. It achieves this be taking into account a number of factors from the field of psychology and applying them in the context of modern computer graphics and interaction with these virtual environments. Furthermore, it does not rely on past data with outdated hardware, but rather on the most recently available hardware combined with modern software.

HMDs have made big improvements since they first enter the public awareness in the 90s. With the recent advances they already offer a wide range of applications beyond gaming while providing an immersive experience.Regarding the findings they, albeit limited in their breath, support the observed trend in some regard. While the spatial perception was different in HMD when compared to standard flat presentation, they were not consistent enough to make out specific areas like small vs large objects or width vs height estimation. In comparison the evidence points towards the peripheral perception as being more affected by the different type of reality with subjects even sometimes scoring better than in the real world. Regarding prior experience there was only limited evidence to separate past virtual ones from past real ones. While there is data pointing out a correlation, it is likely more linked to the peripheral perception than the actual amount of experience had. This lack of conclusive data might be also caused by the general challenge in determining what prior experiences are relevant in the different realities. The way emotions are effected might suffer from a similar problem as there was only limited evidence for a correlation. However, it was more conclusive and points towards certain emotions such as fear being more influenced than others like surprise. In general it can be said that there is an impact on the perception, which puts the HMD based virtual reality more in the middle between the real reality and a virtual world experienced on a flat device like a TV.

Bibliography

[1] I. E. Sutherland. „The Ultimate Display". In: *Proceedings of the IFIP Congress*. 1965.

[2] I. E. Sutherland. „A Head-mounted Three Dimensional Display". In: *Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, Part I*. AFIPS '68 (Fall, part I). New York, NY, USA: ACM, 1968, pp. 757–764. DOI: 10.1145/1476589.1476686. URL: http://doi.acm.org/10.1145/1476589.1476686.

[3] C. Conn et al. „Virtual environments and interactivity: windows to the future". In: *ACM SIGGRAPH 89 Panel Proceedings*. Ed. by R. L. Judd, pp. 7–18. DOI: 10.1145/77276.77278.

[4] M. W. Krueger, T. Gionfriddo, and K. Hinrichsen. „VIDEOPLACE—an artificial reality". In: *the SIGCHI conference*. Ed. by L. Borman and R. Smith, pp. 35–40. DOI: 10.1145/317456.317463.

[5] S. S. Fisher et al. „Virtual environment display system". In: *the 1986 workshop*. Ed. by F. Crow and S. M. Pizer, pp. 77–87. DOI: 10.1145/319120.319127.

[6] M. Agrawala et al. „The two-user Responsive Workbench". In: *the 24th annual conference*. Ed. by G. S. Owen, T. Whitted, and B. Mones-Hattal, pp. 327–332. DOI: 10.1145/258734.258875.

[7] H. H. Bülthoff and C. Christou. „The Perception of Spatial Layout in a Virtual World". In: *Proceedings of the First IEEE International Workshop on Biologically Motivated Computer Vision*. BMVC '00. London, UK, UK: Springer-Verlag, 2000, pp. 10–19. ISBN: 3-540-67560-4. URL: http://dl.acm.org/citation.cfm?id=648247.753986.

[8] V. Interrante et al. „Elucidating Factors That Can Facilitate Veridical Spatial Perception in Immersive Virtual Environments". In: *Presence: Teleoper. Virtual Environ.* 17.2 (2008), pp. 176–198. ISSN: 1054-7460. DOI: 10.1162/pres.17.2.176. URL: http://dx.doi.org/10.1162/pres.17.2.176.

[9] C. Roca-Gonzalez and M. Martinguez. „Training to Improve Spatial Orientation in Engineering Students Using Virtual Environments". In: *Virtual, Augmented and Mixed Reality. Applications of Virtual and Augmented Reality*. Springer, 2014, pp. 96–104.

[10] D. Henry. „Spatial perception in virtual environments: Evaluating an architectural application". In: *Virtual Reality Annual International Symposium, 1993., 1993 IEEE*. IEEE, 1993, pp. 33–40.

[11] A. E. Richardson, D. R. Montello, and M. Hegarty. „Spatial knowledge acquisition from maps and from navigation in real and virtual environments". In: *Memory & Cognition* 27.4 (1999), pp. 741–750. ISSN: 0090-502X. DOI: 10.3758/BF03211566.

[12] F. C. Fortenbaugh et al. „High-speed navigators: Using more than what meets the eye". In: *Journal of Vision* 6.5 (2006), p. 3. ISSN: 1534-7362. DOI: 10.1167/6.5.3.

[13] J. Diemer et al. „The impact of perception and presence on emotional reactions: a review of research in virtual reality". In: *Frontiers in Psychology* 6 (2015), p. 26. DOI: 10.3389/fpsyg.2015.00026.

[14] D. Opris et al. „Virtual reality exposure therapy in anxiety disorders: A quantitative meta-analysis". In: *Depression and Anxiety* 29.2 (2012), pp. 85–93. ISSN: 10914269. DOI: 10.1002/da.20910.

[15] L. F. Hodges et al. „Virtual environments for treating the fear of heights". In: *Computer* 28.7 (1995), pp. 27–34. ISSN: 0018-9162. DOI: 10.1109/2.391038.

[16] I. Alsina-Jurnet, J. Gutiérrez-Maldonado, and M.-V. Rangel-Gómez. „The role of presence in the level of anxiety experienced in clinical virtual environments". In: *Computers in Human Behavior* 27.1 (2011), pp. 504–512. ISSN: 07475632. DOI: 10.1016/j.chb.2010.09.018.

[17] Y. Ling et al. „Effects of Stereoscopic Viewing on Presence, Anxiety, and Cybersickness in a Virtual Reality Environment for Public Speaking". In: *Presence: Teleoperators and Virtual Environments* 21.3 (2012), pp. 254–267. ISSN: 1054-7460. DOI: 10.1162/PRES{_}a{_}00111.

[18] N. Averbukh. „Subjective-Situational Study of Presence". In: *Virtual, Augmented and Mixed Reality. Designing and Developing Virtual and Augmented Environments*. Springer, 2014, pp. 131–138.

[19] E. Neidhardt and M. Popp. „Spatial tests, familiarity with the surroundings, and spatial activity experience". In: *Journal of Individual Differences* (2010).

[20] N. Newcombe and L. S. Liben. „Barrier effects in the cognitive maps of children and adults". In: *Journal of Experimental Child Psychology* 34.1 (1982), pp. 46–58. ISSN: 00220965. DOI: 10.1016/0022-0965(82)90030-3.

[21] S. M. Kosslyn, H. L. Pick, and G. R. Fariello. „Cognitive Maps in Children and Men". In: *Child Development* 45.3 (1974), p. 707. ISSN: 00093920. DOI: 10.2307/1127837.

[22] K. Procci, J. Bohnsack, and C. Bowers. „Patterns of Gaming Preferences and Serious Game Effectiveness". In: *Proceedings of the 2011 International Conference on Virtual and Mixed Reality: Systems and Applications - Volume Part II*. Berlin, Heidelberg: Springer-Verlag, 2011, pp. 37–43. ISBN: 978-3-642-22023-4. URL: http://dl.acm.org/citation.cfm?id=2028716.2028722.

[23] K. SUBRAHMANYAM and P. Greenfield. „Effect of Video Game Practice on Spatial Skills in Girls and Boys". In: *JOURNAL OF APPLIED DEVELOPMENTAL PSYCHOLOGY* 15 (1994), pp. 13–32.

[24] M. M. Bradley and P. J. Lang. „Measuring emotion: The self-assessment manikin and the semantic differential". In: *Journal of Behavior Therapy and Experimental Psychiatry* 25.1 (1994), pp. 49–59. ISSN: 00057916. DOI: 10.1016/0005-7916(94)90063-9.

[25] R. Plutchik. „The Nature of Emotions". In: *American Scientist* 89.4 (2001), p. 344. ISSN: 0003-0996. DOI: 10.1511/2001.4.344.

[26] M. C. Linn and A. C. Petersen. „Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis". In: *Child Development* 56.6 (1985), p. 1479. ISSN: 00093920. DOI: 10.2307/1130467.

[27] D. Kanter. „GRAPHICS PROCESSING REQUIREMENTS FOR ENABLING IMMERSIVE VR: Sponsored by AMD". In: (2015). URL: http://amd-dev.wpengine.netdna-cdn.com/wordpress/media/2012/10/gr_proc_req_for_enabling_immer_VR.pdf (visited on 04/17/2016).

[28] D. Lanman and D. Luebke. „Near-eye Light Field Displays". In: *ACM Trans. Graph.* 32.6 (2013), 220:1–220:10. ISSN: 0730-0301. DOI: 10.1145/2508363.2508366. URL: http://doi.acm.org/10.1145/2508363.2508366.

Appendix A

Appendix

APPENDIX A

APPENDIX

A.1 Correlations matrices for Research Question 3

A.1.1 Hypothesis RQ 3a - Prior real experiences significantly influences 2D distance judging

		In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Warst du als Kind Mitglied bei den Pfadfinder o.ä?	Hast du eine Art des Militärdienst geleistet?	Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Wie groß bist du in m?	Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Was ist der Abstand zwischen den Bodenleuchten in m?	Wie hoch ist der Tunnel in der Mitte in m?	Wie breit ist der Tunnel im m?	Wie breit ist der Pfad zum Tunnel in m?
In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Korrelationskoeffizient	1,000	,175	-,225	-,013	,183	-,049	-,284	-,242	-,140	-,068	-,050	-,201	-,233
	Sig. (2-seitig)	.	,343	,222	,937	,258	,772	,124	,122	,402	,679	,757	,221	,158
	N	24	24	24	24	24	24	21	24	24	24	24	24	24
Warst du als Kind Mitglied bei den Pfadfinder o.ä?	Korrelationskoeffizient	,175	1,000	,174	,323	,240	-,026	-,360	-,035	-,026	-,088	-,198	-,070	-,275
	Sig. (2-seitig)	,343	.	,404	,089	,187	,890	,082	,841	,891	,634	,278	,707	,139
	N	24	24	24	24	24	24	21	24	24	24	24	24	24
Hast du eine Art des Militärdienst geleistet?	Korrelationskoeffizient	-,225	,174	1,000	-,052	,019	,083	,144	,277	,276	,079	-,068	-,179	-,050
	Sig. (2-seitig)	,222	,404	.	,786	,916	,665	,488	,116	,145	,670	,710	,334	,787
	N	24	24	24	24	24	24	21	24	24	24	24	24	24
Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Korrelationskoeffizient	-,013	,323	-,052	1,000	,575**	-,047	-,237	,097	-,121	,049	-,097	-,095	-,237
	Sig. (2-seitig)	,937	,089	,786	.	,001	,787	,212	,550	,486	,771	,561	,576	,163
	N	24	24	24	24	24	24	21	24	24	24	24	24	24
Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Korrelationskoeffizient	,183	,240	,019	,575**	1,000	-,066	-,223	-,020	-,074	-,017	-,078	-,110	-,307
	Sig. (2-seitig)	,258	,187	,916	,001	.	,694	,218	,899	,657	,918	,625	,500	,060
	N	24	24	24	24	24	24	21	24	24	24	24	24	24
Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Korrelationskoeffizient	-,049	-,026	,083	-,047	-,066	1,000	,115	,198	-,093	,121	-,027	-,023	,160
	Sig. (2-seitig)	,772	,890	,665	,787	,694	.	,547	,223	,593	,475	,874	,894	,349
	N	24	24	24	24	24	24	21	24	24	24	24	24	24
Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Korrelationskoeffizient	-,284	-,360	,144	-,237	-,223	,115	1,000	,034	-,006	-,253	,082	-,006	-,068
	Sig. (2-seitig)	,124	,082	,488	,212	,218	,547	.	,847	,974	,170	,650	,974	,716
	N	21	21	21	21	21	21	21	21	21	21	21	21	21
Wie groß bist du in m?	Korrelationskoeffizient	-,242	-,035	,277	,097	-,020	,198	,034	1,000	-,120	,362*	-,039	,276	,371*
	Sig. (2-seitig)	,122	,841	,116	,550	,899	,223	,847	.	,454	,022	,800	,081	,019
	N	24	24	24	24	24	24	21	24	24	24	24	24	24
Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Korrelationskoeffizient	-,140	-,026	,276	-,121	-,074	-,093	-,006	-,120	1,000	,102	,270	-,175	-,023
	Sig. (2-seitig)	,402	,891	,145	,486	,657	,593	,974	,454	.	,545	,104	,302	,894
	N	24	24	24	24	24	24	21	24	24	24	24	24	24
Was ist der Abstand zwischen den Bodenleuchten in m?	Korrelationskoeffizient	-,068	-,088	,079	,049	-,017	,121	-,253	,362*	,102	1,000	,279	,385*	,553**
	Sig. (2-seitig)	,679	,634	,670	,771	,918	,475	,170	,022	,545	.	,088	,020	,001
	N	24	24	24	24	24	24	21	24	24	24	24	24	24
Wie hoch ist der Tunnel in der Mitte in m?	Korrelationskoeffizient	-,050	-,198	-,068	-,097	-,078	-,027	,082	-,039	,270	,279	1,000	,128	,064
	Sig. (2-seitig)	,757	,278	,710	,561	,625	,874	,650	,800	,104	,088	.	,435	,695
	N	24	24	24	24	24	24	21	24	24	24	24	24	24
Wie breit ist der Tunnel im m?	Korrelationskoeffizient	-,201	-,070	-,179	-,095	-,110	-,023	-,006	,276	-,175	,385*	,128	1,000	,532**
	Sig. (2-seitig)	,221	,707	,334	,576	,500	,894	,974	,081	,302	,020	,435	.	,001
	N	24	24	24	24	24	24	21	24	24	24	24	24	24
Wie breit ist der Pfad zum Tunnel in m?	Korrelationskoeffizient	-,233	-,275	-,050	-,237	-,307	,160	-,068	,371*	-,023	,553**	,064	,532**	1,000
	Sig. (2-seitig)	,158	,139	,787	,163	,060	,349	,716	,019	,894	,001	,695	,001	.
	N	24	24	24	24	24	24	21	24	24	24	24	24	24

(Kendall-Tau-b)

Figure A.1: HMD

		In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Warst du als Kind Mitglied bei den Pfadfinder o.ä?	Hast du eine Art des Militärdienst geleistet?	Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Wie groß bist du in m?	Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Was ist der Abstand zwischen den Bodenleuchten in m?	Wie hoch ist der Tunnel in der Mitte in m?	Wie breit ist der Tunnel im m?	Wie breit ist der Pfad zum Tunnel in m?
In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Korrelationskoeffizient	1,000	,531	-,229	,221	,513	-,349	-,035	,058	-,082	-,109	,122	-,106	,000
	Sig. (2-seitig)		,022	,324	,287	,013	,098	,872	,775	,694	,599	,560	,620	1,000
	N	16	16	16	16	16	16	15	16	16	16	16	16	16
Warst du als Kind Mitglied bei den Pfadfinder o.ä?	Korrelationskoeffizient	,531	1,000	,153	,215	,421	-,356	-,184	-,052	,303	-,331	,203	-,057	,121
	Sig. (2-seitig)	,022	.	,554	,350	,065	,127	,448	,818	,192	,149	,379	,811	,599
	N	16	16	16	16	16	16	15	16	16	16	16	16	16
Hast du eine Art des Militärdienst geleistet?	Korrelationskoeffizient	-,229	,153	1,000	-,056	,037	,249	-,085	,073	,463	-,019	,361	,198	-,113
	Sig. (2-seitig)	,324	,554	.	,806	,872	,286	,726	,747	,046	,936	,119	,403	,623
	N	16	16	16	16	16	16	15	16	16	16	16	16	16
Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Korrelationskoeffizient	,221	,215	-,056	1,000	,330	-,141	-,068	-,115	-,315	,039	-,040	-,490	-,199
	Sig. (2-seitig)	,287	,350	,806	.	,106	,498	,752	,569	,129	,849	,847	,020	,335
	N	16	16	16	16	16	16	15	16	16	16	16	16	16
Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Korrelationskoeffizient	,513	,421	,037	,330	1,000	-,168	-,171	-,085	,080	-,019	-,049	,113	-,263
	Sig. (2-seitig)	,013	,065	,872	,106	.	,417	,430	,673	,699	,925	,811	,592	,199
	N	16	16	16	16	16	16	15	16	16	16	16	16	16
Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Korrelationskoeffizient	-,349	-,356	,249	-,141	-,168	1,000	,186	-,147	-,021	,219	,000	,373	,213
	Sig. (2-seitig)	,098	,127	,286	,498	,417	.	,396	,474	,922	,293	1,000	,083	,309
	N	16	16	16	16	16	16	15	16	16	16	16	16	16
Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Korrelationskoeffizient	-,035	-,184	-,085	-,068	-,171	,186	1,000	,363	-,096	,034	,221	,216	,241
	Sig. (2-seitig)	,872	,448	,726	,752	,430	,396	.	,086	,663	,874	,310	,332	,266
	N	15	15	15	15	15	15	15	15	15	15	15	15	15
Wie groß bist du in m?	Korrelationskoeffizient	,058	-,052	,073	-,115	-,085	-,147	,363	1,000	-,098	-,123	,300	-,141	,029
	Sig. (2-seitig)	,775	,818	,747	,569	,673	,474	,086	.	,630	,542	,139	,496	,887
	N	16	16	16	16	16	16	15	16	16	16	16	16	16
Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Korrelationskoeffizient	-,082	,303	,463	-,315	,080	-,021	-,096	-,098	1,000	,030	,236	,332	,082
	Sig. (2-seitig)	,694	,192	,046	,129	,699	,922	,663	,630	.	,885	,258	,120	,695
	N	16	16	16	16	16	16	15	16	16	16	16	16	16
Was ist der Abstand zwischen den Bodenleuchten in m?	Korrelationskoeffizient	-,109	-,331	-,019	,039	-,019	,219	,034	-,123	,030	1,000	,059	,093	-,059
	Sig. (2-seitig)	,599	,149	,936	,849	,925	,293	,874	,542	,885	.	,774	,661	,775
	N	16	16	16	16	16	16	15	16	16	16	16	16	16
Wie hoch ist der Tunnel in der Mitte in m?	Korrelationskoeffizient	,122	,203	,361	-,040	-,049	,000	,221	,300	,236	,059	1,000	,137	,141
	Sig. (2-seitig)	,560	,379	,119	,847	,811	1,000	,310	,139	,258	,774	.	,520	,498
	N	16	16	16	16	16	16	15	16	16	16	16	16	16
Wie breit ist der Tunnel im m?	Korrelationskoeffizient	-,106	-,057	,198	-,490	,113	,373	,216	-,141	,332	,093	,137	1,000	,115
	Sig. (2-seitig)	,620	,811	,403	,020	,592	,083	,332	,496	,120	,661	,520	.	,587
	N	16	16	16	16	16	16	15	16	16	16	16	16	16
Wie breit ist der Pfad zum Tunnel in m?	Korrelationskoeffizient	,000	,121	-,113	-,199	-,263	,213	,241	,029	,082	-,059	,141	,115	1,000
	Sig. (2-seitig)	1,000	,599	,623	,335	,199	,309	,266	,887	,695	,775	,498	,587	.
	N	16	16	16	16	16	16	15	16	16	16	16	16	16

Kendall-Tau-b

Figure A.2: Real

Kendall-Tau-b

		In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Warst du als Kind Mitglied bei den Pfadfinder o.ä?	Hast du eine Art des Militärdienst geleistet?	Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Wie groß bist du in m?	Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Was ist der Abstand zwischen den Bodenleuchten in m?	Wie hoch ist der Tunnel in der Mitte in m?	Wie breit ist der Tunnel im m?	Wie breit ist der Pfad zum Tunnel in m?
In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Korrelationskoeffizient	1,000	-,214	-,321	-,077	,091	,047	-,272	,255	-,112	-,201	,000	,018	,071
	Sig. (2-seitig)	.	,290	,113	,677	,612	,805	,196	,136	,545	,263	1,000	,919	,687
	N	20	20	20	20	20	20	16	20	20	20	20	20	20
Warst du als Kind Mitglied bei den Pfadfinder o.ä?	Korrelationskoeffizient	-,214	1,000	-,053	,095	,072	-,257	,321	,201	,156	-,198	-,053	,164	,140
	Sig. (2-seitig)	,290	.	,819	,650	,723	,231	,176	,298	,457	,329	,792	,424	,483
	N	20	20	20	20	20	20	16	20	20	20	20	20	20
Hast du eine Art des Militärdienst geleistet?	Korrelationskoeffizient	-,321	-,053	1,000	-,342	,072	-,257	-,187	,319	,059	-,198	-,264	-,273	-,262
	Sig. (2-seitig)	,113	,819	.	,103	,723	,231	,430	,099	,780	,329	,187	,183	,188
	N	20	20	20	20	20	20	16	20	20	20	20	20	20
Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Korrelationskoeffizient	-,077	,095	-,342	1,000	,364	,093	,011	-,212	,134	-,098	,171	-,092	-,126
	Sig. (2-seitig)	,677	,650	,103	.	,051	,637	,960	,232	,486	,600	,350	,624	,489
	N	20	20	20	20	20	20	16	20	20	20	20	20	20
Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Korrelationskoeffizient	,091	,072	,072	,364	1,000	-,196	-,072	,184	-,201	-,241	,121	-,019	-,180
	Sig. (2-seitig)	,612	,723	,723	,051	.	,304	,736	,287	,283	,184	,500	,918	,312
	N	20	20	20	20	20	20	16	20	20	20	20	20	20
Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Korrelationskoeffizient	,047	-,257	-,257	,093	-,196	1,000	,159	-,113	,015	,203	,106	-,157	,177
	Sig. (2-seitig)	,805	,231	,231	,637	,304	.	,476	,532	,941	,287	,574	,414	,343
	N	20	20	20	20	20	20	16	20	20	20	20	20	20
Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Korrelationskoeffizient	-,272	,321	-,187	,011	-,072	,159	1,000	,000	-,063	,010	-,040	,031	-,020
	Sig. (2-seitig)	,196	,176	,430	,960	,736	,476	.	1,000	,769	,962	,849	,884	,924
	N	16	16	16	16	16	16	16	16	16	16	16	16	16
Wie groß bist du in m?	Korrelationskoeffizient	,255	,201	,319	-,212	,184	-,113	,000	1,000	-,174	-,184	-,163	-,122	-,100
	Sig. (2-seitig)	,136	,298	,099	,232	,287	,532	1,000	.	,327	,286	,338	,483	,553
	N	20	20	20	20	20	20	16	20	20	20	20	20	20
Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Korrelationskoeffizient	-,112	,156	,059	,134	-,201	,015	-,063	-,174	1,000	,107	,007	,162	,260
	Sig. (2-seitig)	,545	,457	,780	,486	,283	,941	,769	,327	.	,566	,972	,389	,156
	N	20	20	20	20	20	20	16	20	20	20	20	20	20
Was ist der Abstand zwischen den Bodenleuchten in m?	Korrelationskoeffizient	-,201	-,198	-,198	-,098	-,241	,203	,010	-,184	,107	1,000	,422[*]	,280	,365[*]
	Sig. (2-seitig)	,263	,329	,329	,600	,184	,287	,962	,286	,566	.	,018	,124	,039
	N	20	20	20	20	20	20	16	20	20	20	20	20	20
Wie hoch ist der Tunnel in der Mitte in m?	Korrelationskoeffizient	,000	-,053	-,264	,171	,121	,106	-,040	-,163	,007	,422[*]	1,000	,365[*]	,351[*]
	Sig. (2-seitig)	1,000	,792	,187	,350	,500	,574	,849	,338	,972	,018	.	,042	,045
	N	20	20	20	20	20	20	16	20	20	20	20	20	20
Wie breit ist der Tunnel im m?	Korrelationskoeffizient	,018	,164	-,273	-,092	-,019	-,157	,031	-,122	,162	,280	,365[*]	1,000	,556[**]
	Sig. (2-seitig)	,919	,424	,183	,624	,918	,414	,884	,483	,389	,124	,042	.	,002
	N	20	20	20	20	20	20	16	20	20	20	20	20	20
Wie breit ist der Pfad zum Tunnel in m?	Korrelationskoeffizient	,071	,140	-,262	-,126	-,180	,177	-,020	-,100	,260	,365[*]	,351[*]	,556[**]	1,000
	Sig. (2-seitig)	,687	,483	,188	,489	,312	,343	,924	,553	,156	,039	,045	,002	.
	N	20	20	20	20	20	20	16	20	20	20	20	20	20

Figure A.3: TV

A.1.2 Hypothesis RQ 3b - Prior real experiences significantly influences 3D Space judging

		In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Hast du eine Art des Militärdienst geleistet?	Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Wie groß bist du in m?	Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?
In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Korrelationskoeffizient	1,000	,175	-,225	-,013	,183	-,049	-,284	-,242	-,140
	Sig. (2-seitig)	.	,343	,222	,937	,258	,772	,124	,122	,402
	N	24	24	24	24	24	24	21	24	24
Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Korrelationskoeffizient	,175	1,000	,174	,323	,240	-,026	-,360	-,035	-,026
	Sig. (2-seitig)	,343	.	,404	,089	,187	,890	,082	,841	,891
	N	24	24	24	24	24	24	21	24	24
Hast du eine Art des Militärdienst geleistet?	Korrelationskoeffizient	-,225	,174	1,000	-,052	,019	,083	,144	,277	,276
	Sig. (2-seitig)	,222	,404	.	,786	,916	,665	,488	,116	,145
	N	24	24	24	24	24	24	21	24	24
Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Korrelationskoeffizient	-,013	,323	-,052	1,000	,575	-,047	-,237	,097	-,121
	Sig. (2-seitig)	,937	,089	,786	.	,001	,787	,212	,550	,486
	N	24	24	24	24	24	24	21	24	24
Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Korrelationskoeffizient	,183	,240	,019	,575	1,000	-,066	-,223	-,020	-,074
	Sig. (2-seitig)	,258	,187	,916	,001	.	,694	,218	,899	,657
	N	24	24	24	24	24	24	21	24	24
Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Korrelationskoeffizient	-,049	-,026	,083	-,047	-,066	1,000	,115	,198	-,093
	Sig. (2-seitig)	,772	,890	,665	,787	,694	.	,547	,223	,593
	N	24	24	24	24	24	24	21	24	24
Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Korrelationskoeffizient	-,284	-,360	,144	-,237	-,223	,115	1,000	,034	-,006
	Sig. (2-seitig)	,124	,082	,488	,212	,218	,547	.	,847	,974
	N	21	21	21	21	21	21	21	21	21
Wie groß bist du in m?	Korrelationskoeffizient	-,242	-,035	,277	,097	-,020	,198	,034	1,000	-,120
	Sig. (2-seitig)	,122	,841	,116	,550	,899	,223	,847	.	,454
	N	24	24	24	24	24	24	21	24	24
Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Korrelationskoeffizient	-,140	-,026	,276	-,121	-,074	-,093	-,006	-,120	1,000
	Sig. (2-seitig)	,402	,891	,145	,486	,657	,593	,974	,454	.
	N	24	24	24	24	24	24	21	24	24
How high is the well in m? (Deviation)	Korrelationskoeffizient	,056	-,124	,055	-,252	-,228	-,013	,243	-,053	,199
	Sig. (2-seitig)	,722	,483	,753	,119	,142	,938	,168	,727	,216
	N	24	24	24	24	24	24	21	24	24
How wide is the Kurtine in m? (Deviation)	Korrelationskoeffizient	,126	-,145	-,095	,082	,052	-,198	-,099	-,258	,217
	Sig. (2-seitig)	,429	,420	,599	,619	,741	,230	,583	,092	,186
	N	24	24	24	24	24	24	21	24	24
How high is the smaller tree in front of the tunnel in m? (Deviation)	Korrelationskoeffizient	-,063	-,205	-,019	,181	,227	,142	,030	,119	-,162
	Sig. (2-seitig)	,699	,263	,915	,278	,157	,399	,871	,446	,332
	N	24	24	24	24	24	24	21	24	24
How high is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	-,159	-,176	-,066	,104	,052	,009	-,035	,015	,119
	Sig. (2-seitig)	,318	,329	,712	,529	,740	,958	,846	,920	,466
	N	24	24	24	24	24	24	21	24	24
How wide is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	-,020	,323	,047	-,030	-,103	-,162	-,270	-,027	-,013
	Sig. (2-seitig)	,899	,070	,793	,855	,509	,323	,130	,861	,938
	N	24	24	24	24	24	24	21	24	24
How high is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	-,004	,110	-,230	-,157	-,208	-,083	-,064	,031	-,022
	Sig. (2-seitig)	,980	,544	,205	,344	,192	,619	,723	,840	,896
	N	24	24	24	24	24	24	21	24	24
How wide is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	-,164	,104	,258	-,091	-,276	,048	-,150	,140	,017
	Sig. (2-seitig)	,304	,566	,153	,581	,082	,773	,401	,363	,917
	N	24	24	24	24	24	24	21	24	24
How high is the opposite wall in m? (Deviation)	Korrelationskoeffizient	-,026	-,152	,080	-,145	-,228	,072	-,060	,372	-,107
	Sig. (2-seitig)	,876	,412	,668	,394	,161	,671	,743	,018	,526
	N	24	24	24	24	24	24	21	24	24

Kendall-Tau-b

Figure A.4: HMD

Kendall-Tau-b

		In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Hast du eine Art des Militärdienst geleistet?	Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Wie groß bist du in m?	Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?
In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Korrelationskoeffizient	1,000	,531	-,229	,221	,513	-,349	-,035	,058	-,082
	Sig. (2-seitig)	.	,022	,324	,287	,013	,098	,872	,775	,694
	N	16	16	16	16	16	16	15	16	16
Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Korrelationskoeffizient	,531	1,000	,153	,215	,421	-,356	-,184	-,052	,303
	Sig. (2-seitig)	,022	.	,554	,350	,065	,127	,448	,818	,192
	N	16	16	16	16	16	16	15	16	16
Hast du eine Art des Militärdienst geleistet?	Korrelationskoeffizient	-,229	,153	1,000	-,056	,037	,249	-,085	,073	,463
	Sig. (2-seitig)	,324	,554	.	,806	,872	,286	,726	,747	,046
	N	16	16	16	16	16	16	15	16	16
Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Korrelationskoeffizient	,221	,215	-,056	1,000	,330	-,141	-,068	-,115	-,315
	Sig. (2-seitig)	,287	,350	,806	.	,106	,498	,752	,569	,129
	N	16	16	16	16	16	16	15	16	16
Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Korrelationskoeffizient	,513	,421	,037	,330	1,000	-,168	-,171	-,085	,080
	Sig. (2-seitig)	,013	,065	,872	,106	.	,417	,430	,673	,699
	N	16	16	16	16	16	16	15	16	16
Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Korrelationskoeffizient	-,349	-,356	,249	-,141	-,168	1,000	,186	-,147	-,021
	Sig. (2-seitig)	,098	,127	,286	,498	,417	.	,396	,474	,922
	N	16	16	16	16	16	16	15	16	16
Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Korrelationskoeffizient	-,035	-,184	-,085	-,068	-,171	,186	1,000	,363	-,096
	Sig. (2-seitig)	,872	,448	,726	,752	,430	,396	.	,086	,663
	N	15	15	15	15	15	15	15	15	15
Wie groß bist du in m?	Korrelationskoeffizient	,058	-,052	,073	-,115	-,085	-,147	,363	1,000	-,098
	Sig. (2-seitig)	,775	,818	,747	,569	,673	,474	,086	.	,630
	N	16	16	16	16	16	16	15	16	16
Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Korrelationskoeffizient	-,082	,303	,463	-,315	,080	-,021	-,096	-,098	1,000
	Sig. (2-seitig)	,694	,192	,046	,129	,699	,922	,663	,630	.
	N	16	16	16	16	16	16	15	16	16
How high is the well in m? (Deviation)	Korrelationskoeffizient	,248	,459	,321	-,122	,101	-,038	-,098	,318	,318
	Sig. (2-seitig)	,219	,040	,150	,541	,610	,850	,641	,105	,115
	N	16	16	16	16	16	16	15	16	16
How wide is the Kurtine in m? (Deviation)	Korrelationskoeffizient	-,177	-,087	,104	-,229	,009	,037	,492	,248	,188
	Sig. (2-seitig)	,372	,691	,633	,243	,963	,851	,018	,198	,343
	N	16	16	16	16	16	16	15	16	16
How high is the smaller tree in front of the tunnel in m? (Deviation)	Korrelationskoeffizient	,114	,254	,391	,028	,037	-,038	-,164	,081	,470
	Sig. (2-seitig)	,571	,254	,079	,888	,853	,850	,436	,677	,019
	N	16	16	16	16	16	16	15	16	16
How high is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	,000	,151	,070	-,130	-,328	-,133	,141	,260	,266
	Sig. (2-seitig)	1,000	,495	,750	,512	,096	,510	,501	,181	,183
	N	16	16	16	16	16	16	15	16	16
How wide is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	-,172	-,051	,321	,113	,092	,019	,318	,045	,222
	Sig. (2-seitig)	,395	,819	,150	,573	,643	,925	,132	,817	,272
	N	16	16	16	16	16	16	15	16	16
How high is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	-,120	-,147	-,131	-,138	-,541	-,101	,305	,143	-,273
	Sig. (2-seitig)	,562	,521	,567	,501	,008	,629	,156	,477	,187
	N	16	16	16	16	16	16	15	16	16
How wide is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	,124	,000	,338	-,103	,119	-,181	-,099	,172	,230
	Sig. (2-seitig)	,539	1,000	,128	,605	,546	,369	,640	,379	,251
	N	16	16	16	16	16	16	15	16	16
How high is the opposite wall in m? (Deviation)	Korrelationskoeffizient	,000	-,026	-,164	,230	-,169	,166	,281	,046	-,403
	Sig. (2-seitig)	1,000	,908	,468	,255	,399	,417	,189	,815	,048
	N	16	16	16	16	16	16	15	16	16

Figure A.5: Real

Kendall-Tau-b

		In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Hast du eine Art des Militärdienst geleistet?	Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Wie groß bist du in m?	Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?
In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Korrelationskoeffizient	1,000	-,214	-,321	-,077	,091	,047	-,272	,255	-,112
	Sig. (2-seitig)	.	,290	,113	,677	,612	,805	,196	,136	,545
	N	20	20	20	20	20	20	16	20	20
Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Korrelationskoeffizient	-,214	1,000	-,053	,095	,072	-,257	,321	,201	,156
	Sig. (2-seitig)	,290	.	,819	,650	,723	,231	,176	,298	,457
	N	20	20	20	20	20	20	16	20	20
Hast du eine Art des Militärdienst geleistet?	Korrelationskoeffizient	-,321	-,053	1,000	-,342	,072	-,257	-,187	,319	,059
	Sig. (2-seitig)	,113	,819	.	,103	,723	,231	,430	,099	,780
	N	20	20	20	20	20	20	16	20	20
Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Korrelationskoeffizient	-,077	,095	-,342	1,000	,364	,093	,011	-,212	,134
	Sig. (2-seitig)	,677	,650	,103	.	,051	,637	,960	,232	,486
	N	20	20	20	20	20	20	16	20	20
Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Korrelationskoeffizient	,091	,072	,072	,364	1,000	-,196	-,072	,184	-,201
	Sig. (2-seitig)	,612	,723	,723	,051	.	,304	,736	,287	,283
	N	20	20	20	20	20	20	16	20	20
Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Korrelationskoeffizient	,047	-,257	-,257	,093	-,196	1,000	,159	-,113	,015
	Sig. (2-seitig)	,805	,231	,231	,637	,304	.	,476	,532	,941
	N	20	20	20	20	20	20	16	20	20
Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Korrelationskoeffizient	-,272	,321	-,187	,011	-,072	,159	1,000	,000	-,063
	Sig. (2-seitig)	,196	,176	,430	,960	,736	,476	.	1,000	,769
	N	16	16	16	16	16	16	16	16	16
Wie groß bist du in m?	Korrelationskoeffizient	,255	,201	,319	-,212	,184	-,113	,000	1,000	-,174
	Sig. (2-seitig)	,136	,298	,099	,232	,287	,532	1,000	.	,327
	N	20	20	20	20	20	20	16	20	20
Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Korrelationskoeffizient	-,112	,156	,059	,134	-,201	,015	-,063	-,174	1,000
	Sig. (2-seitig)	,545	,457	,780	,486	,283	,941	,769	,327	.
	N	20	20	20	20	20	20	16	20	20
How high is the well in m? (Deviation)	Korrelationskoeffizient	-,142	-,070	-,017	,176	,137	-,111	-,139	-,278	,155
	Sig. (2-seitig)	,420	,725	,930	,332	,437	,550	,502	,099	,394
	N	20	20	20	20	20	20	16	20	20
How wide is the Kurtine in m? (Deviation)	Korrelationskoeffizient	,024	,177	-,088	,000	,073	-,272	,089	-,169	-,236
	Sig. (2-seitig)	,893	,379	,660	1,000	,685	,149	,668	,321	,201
	N	20	20	20	20	20	20	16	20	20
How high is the smaller tree in front of the tunnel in m? (Deviation)	Korrelationskoeffizient	-,214	-,154	-,291	,148	-,117	,051	,119	-,594	-,051
	Sig. (2-seitig)	,218	,433	,139	,410	,504	,780	,568	,000	,778
	N	20	20	20	20	20	20	16	20	20
How high is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	-,235	,051	,187	-,128	,157	-,038	-,222	-,195	-,031
	Sig. (2-seitig)	,173	,794	,339	,472	,368	,835	,276	,240	,861
	N	20	20	20	20	20	20	16	20	20
How wide is the wall with the arrowslits in m? (Deviation)	Korrelationskoeffizient	,006	-,017	,068	-,247	-,094	-,045	,174	,022	-,203
	Sig. (2-seitig)	,973	,931	,727	,170	,592	,807	,394	,896	,260
	N	20	20	20	20	20	20	16	20	20
How high is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	-,077	,211	-,158	-,044	,036	,007	,339	-,208	-,059
	Sig. (2-seitig)	,662	,291	,428	,808	,839	,972	,103	,221	,749
	N	20	20	20	20	20	20	16	20	20
How wide is the wall with the 4 Columns in m? (Deviation)	Korrelationskoeffizient	,006	,227	-,279	,264	,257	,020	,040	-,100	-,149
	Sig. (2-seitig)	,973	,254	,160	,147	,147	,916	,849	,553	,415
	N	20	20	20	20	20	20	16	20	20
How high is the opposite wall in m? (Deviation)	Korrelationskoeffizient	-,161	,035	-,211	-,114	,024	,000	,070	-,292	-,007
	Sig. (2-seitig)	,363	,860	,291	,532	,892	1,000	,737	,085	,972
	N	20	20	20	20	20	20	16	20	20

Figure A.6: TV

A.1.3 Hypothesis RQ 3c - Prior real experiences significantly influences peripheral perception

Kendall-Tau-b		In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Hast du eine Art des Militärdienst geleistet?	Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Wie groß bist du in m?	Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?
In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Korrelationskoeffizient	1,000	,175	-,225	-,013	,183	-,049	-,284	-,242	-,140
	Sig. (2-seitig)	.	,343	,222	,937	,258	,772	,124	,122	,402
	N	24	24	24	24	24	24	21	24	24
Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Korrelationskoeffizient	,175	1,000	,174	,323	,240	-,026	-,360	-,035	-,026
	Sig. (2-seitig)	,343	.	,404	,089	,187	,890	,082	,841	,891
	N	24	24	24	24	24	24	21	24	24
Hast du eine Art des Militärdienst geleistet?	Korrelationskoeffizient	-,225	,174	1,000	-,052	,019	,083	,144	,277	,276
	Sig. (2-seitig)	,222	,404	.	,786	,916	,665	,488	,116	,145
	N	24	24	24	24	24	24	21	24	24
Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Korrelationskoeffizient	-,013	,323	-,052	1,000	,575	-,047	-,237	,097	-,121
	Sig. (2-seitig)	,937	,089	,786	.	,001	,787	,212	,550	,486
	N	24	24	24	24	24	24	21	24	24
Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Korrelationskoeffizient	,183	,240	,019	,575	1,000	-,066	-,223	-,020	-,074
	Sig. (2-seitig)	,258	,187	,916	,001	.	,694	,218	,899	,657
	N	24	24	24	24	24	24	21	24	24
Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Korrelationskoeffizient	-,049	-,026	,083	-,047	-,066	1,000	,115	,198	-,093
	Sig. (2-seitig)	,772	,890	,665	,787	,694	.	,547	,223	,593
	N	24	24	24	24	24	24	21	24	24
Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Korrelationskoeffizient	-,284	-,360	,144	-,237	-,223	,115	1,000	,034	-,006
	Sig. (2-seitig)	,124	,082	,488	,212	,218	,547	.	,847	,974
	N	21	21	21	21	21	21	21	21	21
Wie groß bist du in m?	Korrelationskoeffizient	-,242	-,035	,277	,097	-,020	,198	,034	1,000	-,120
	Sig. (2-seitig)	,122	,841	,116	,550	,899	,223	,847	.	,454
	N	24	24	24	24	24	24	21	24	24
Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Korrelationskoeffizient	-,140	-,026	,276	-,121	-,074	-,093	-,006	-,120	1,000
	Sig. (2-seitig)	,402	,891	,145	,486	,657	,593	,974	,454	.
	N	24	24	24	24	24	24	21	24	24
Gab es nur in den Boden gepflanzte Bäume im Schloßhof?	Korrelationskoeffizient	,101	-,110	,037	,123	,178	,096	,000	-,030	-,222
	Sig. (2-seitig)	,577	,590	,856	,509	,319	,610	1,000	,862	,233
	N	24	24	24	24	24	24	21	24	24
Zu wieviele waren die Schießscharten der Kurtinenwand gruppiert? (Abweichung)	Korrelationskoeffizient	-,274	-,174	,091	-,134	-,232	,062	-,144	-,129	,204
	Sig. (2-seitig)	,137	,404	,663	,480	,204	,745	,488	,464	,281
	N	24	24	24	24	24	24	21	24	24
Was ist die Farbe der Baumkübel?	Korrelationskoeffizient	-,194	-,158	-,064	-,371	-,151	,147	,006	-,017	-,063
	Sig. (2-seitig)	,252	,410	,736	,034	,369	,403	,973	,914	,719
	N	24	24	24	24	24	24	21	24	24
War etwas besonders an den Fenstern im Bereich überm Tunnel?	Korrelationskoeffizient	,206	,166	-,219	,147	,438	-,390	-,181	-,047	-,122
	Sig. (2-seitig)	,224	,386	,253	,402	,009	,027	,346	,775	,485
	N	24	24	24	24	24	24	21	24	24
Welche Farbe hatte der Türrahmen in der Wand mit den vier Säulen?	Korrelationskoeffizient	,043	-,228	-,169	-,023	-,156	,000	,106	-,290	,102
	Sig. (2-seitig)	,795	,218	,363	,894	,337	1,000	,572	,065	,543
	N	24	24	24	24	24	24	21	24	24
Welches Symbol war im Seitentunnel zu sehen?	Korrelationskoeffizient	,338	-,040	,000	-,010	,036	,401	,077	-,162	,169
	Sig. (2-seitig)	,047	,835	1,000	,957	,832	,023	,687	,321	,332
	N	24	24	24	24	24	24	21	24	24

Figure A.7: HMD

		In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Hast du eine Art des Militärdienst geleistet?	Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Wie groß bist du in m?	Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?
In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Korrelationskoeffizient	1,000	,531	-,229	,221	,513	-,349	-,035	,058	-,082
	Sig. (2-seitig)	.	,022	,324	,287	,013	,098	,872	,775	,694
	N	16	16	16	16	16	16	15	16	16
Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Korrelationskoeffizient	,531	1,000	,153	,215	,421	-,356	-,184	-,052	,303
	Sig. (2-seitig)	,022	.	,554	,350	,065	,127	,448	,818	,192
	N	16	16	16	16	16	16	15	16	16
Hast du eine Art des Militärdienst geleistet?	Korrelationskoeffizient	-,229	,153	1,000	-,056	,037	,249	-,085	,073	,463
	Sig. (2-seitig)	,324	,554	.	,806	,872	,286	,726	,747	,046
	N	16	16	16	16	16	16	15	16	16
Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Korrelationskoeffizient	,221	,215	-,056	1,000	,330	-,141	-,068	-,115	-,315
	Sig. (2-seitig)	,287	,350	,806	.	,106	,498	,752	,569	,129
	N	16	16	16	16	16	16	15	16	16
Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Korrelationskoeffizient	,513	,421	,037	,330	1,000	-,168	-,171	-,085	,080
	Sig. (2-seitig)	,013	,065	,872	,106	.	,417	,430	,673	,699
	N	16	16	16	16	16	16	15	16	16
Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Korrelationskoeffizient	-,349	-,356	,249	-,141	-,168	1,000	,186	-,147	-,021
	Sig. (2-seitig)	,098	,127	,286	,498	,417	.	,396	,474	,922
	N	16	16	16	16	16	16	15	16	16
Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Korrelationskoeffizient	-,035	-,184	-,085	-,068	-,171	,186	1,000	,363	-,096
	Sig. (2-seitig)	,872	,448	,726	,752	,430	,396	.	,086	,663
	N	15	15	15	15	15	15	15	15	15
Wie groß bist du in m?	Korrelationskoeffizient	,058	-,052	,073	-,115	-,085	-,147	,363	1,000	-,098
	Sig. (2-seitig)	,775	,818	,747	,569	,673	,474	,086	.	,630
	N	16	16	16	16	16	16	15	16	16
Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Korrelationskoeffizient	-,082	,303	,463	-,315	,080	-,021	-,096	-,098	1,000
	Sig. (2-seitig)	,694	,192	,046	,129	,699	,922	,663	,630	.
	N	16	16	16	16	16	16	15	16	16
Gab es nur in den Boden gepflanzte Bäume im Schloßhof?	Korrelationskoeffizient	-,038	,000	,070	-,136	-,303	,088	,153	,263	-,038
	Sig. (2-seitig)	,868	1,000	,780	,545	,175	,699	,527	,233	,867
	N	16	16	16	16	16	16	15	16	16
Zu wieviele waren die Schießscharten der Kurtinenwand gruppiert? (Abweichung)	Korrelationskoeffizient	,411	-,017	-,432	,076	,149	,116	,201	,134	-,298
	Sig. (2-seitig)	,066	,945	,081	,731	,498	,605	,387	,535	,181
	N	16	16	16	16	16	16	15	16	16
Was ist die Farbe der Baumkübel?	Korrelationskoeffizient	,333	,000	,000	,410	,590	-,112	-,201	-,093	,098
	Sig. (2-seitig)	,137	1,000	1,000	,064	,007	,620	,388	,670	,661
	N	16	16	16	16	16	16	15	16	16
War etwas besonders an den Fenstern im Bereich überm Tunnel?	Korrelationskoeffizient	,142	,451	,122	,172	-,095	,099	,210	-,031	,242
	Sig. (2-seitig)	,515	,062	,612	,425	,658	,652	,353	,883	,265
	N	16	16	16	16	16	16	15	16	16
Welche Farbe hatte der Türrahmen in der Wand mit den vier Säulen?	Korrelationskoeffizient	,364	,364	-,076	-,060	,088	-,467	-,247	,260	,184
	Sig. (2-seitig)	,081	,115	,743	,772	,669	,026	,261	,200	,378
	N	16	16	16	16	16	16	15	16	16
Welches Symbol war im Seitentunnel zu sehen?	Korrelationskoeffizient	-,158	,042	-,177	,280	-,152	-,222	,425	-,105	,032
	Sig. (2-seitig)	,488	,868	,484	,215	,496	,332	,079	,634	,889
	N	16	16	16	16	16	16	15	16	16

(Zeilenbeschriftung links: Kendall-Tau-b)

Figure A.8: Real

		In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Hast du eine Art des Militärdienst geleistet?	Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Wie groß bist du in m?	Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?
In welcher Art Stadt hast du den Großteil deiner Kindheit verbracht?	Korrelationskoeffizient	1,000	-,214	-,321	-,077	,091	,047	-,272	,255	-,112
	Sig. (2-seitig)	.	,290	,113	,677	,612	,805	,196	,136	,545
	N	20	20	20	20	20	20	16	20	20
Warst du als Kind Mitglied bei den Pfadfinder o.ä ?	Korrelationskoeffizient	-,214	1,000	-,053	,095	,072	-,257	,321	,201	,156
	Sig. (2-seitig)	,290	.	,819	,650	,723	,231	,176	,298	,457
	N	20	20	20	20	20	20	16	20	20
Hast du eine Art des Militärdienst geleistet?	Korrelationskoeffizient	-,321	-,053	1,000	-,342	,072	-,257	-,187	,319	,059
	Sig. (2-seitig)	,113	,819	.	,103	,723	,231	,430	,099	,780
	N	20	20	20	20	20	20	16	20	20
Ab welchem Alter bist du als Kind allein/ohne Begleitung regelmäßig zu Orten wie der Schule gegangen?	Korrelationskoeffizient	-,077	,095	-,342	1,000	,364	,093	,011	-,212	,134
	Sig. (2-seitig)	,677	,650	,103	.	,051	,637	,960	,232	,486
	N	20	20	20	20	20	20	16	20	20
Ab welchem Alter bist du als Kind allein/ohne Begleitung unregelmäßig zu Orten wie Freunden oder in die Stadt gegangen?	Korrelationskoeffizient	,091	,072	,072	,364	1,000	-,196	-,072	,184	-,201
	Sig. (2-seitig)	,612	,723	,723	,051	.	,304	,736	,287	,283
	N	20	20	20	20	20	20	16	20	20
Welches Transportmittel hast du häufig benutzt bevor du deinen Führerschein hattest?	Korrelationskoeffizient	,047	-,257	-,257	,093	-,196	1,000	,159	-,113	,015
	Sig. (2-seitig)	,805	,231	,231	,637	,304	.	,476	,532	,941
	N	20	20	20	20	20	20	16	20	20
Welches Transportmittel nutzt du häufig seitdem du deinen Führerschein hast?	Korrelationskoeffizient	-,272	,321	-,187	,011	-,072	,159	1,000	,000	-,063
	Sig. (2-seitig)	,196	,176	,430	,960	,736	,476	.	1,000	,769
	N	16	16	16	16	16	16	16	16	16
Wie groß bist du in m?	Korrelationskoeffizient	,255	,201	,319	-,212	,184	-,113	,000	1,000	-,174
	Sig. (2-seitig)	,136	,298	,099	,232	,287	,532	1,000	.	,327
	N	20	20	20	20	20	20	16	20	20
Wie oft warst du in den letzten vier Jahren (Seit Ende der Buga) auf der Festung?	Korrelationskoeffizient	-,112	,156	,059	,134	-,201	,015	-,063	-,174	1,000
	Sig. (2-seitig)	,545	,457	,780	,486	,283	,941	,769	,327	.
	N	20	20	20	20	20	20	16	20	20
Gab es nur in den Boden gepflanzte Bäume im Schloßhof?	Korrelationskoeffizient	-,379	,025	,025	-,147	-,323	,115	,460	-,187	,095
	Sig. (2-seitig)	,054	,909	,909	,470	,103	,582	,046	,320	,643
	N	20	20	20	20	20	20	16	20	20
Zu wieviele waren die Schießscharten der Kurtinenwand gruppiert? (Abweichung)	Korrelationskoeffizient	,053	-,032	-,032	-,091	-,205	-,142	,347	,050	-,257
	Sig. (2-seitig)	,789	,889	,889	,659	,306	,502	,138	,792	,213
	N	20	20	20	20	20	20	16	20	20
Was ist die Farbe der Baumkübel?	Korrelationskoeffizient	-,195	,130	,241	-,301	,019	-,167	-,093	,118	,282
	Sig. (2-seitig)	,288	,530	,244	,112	,918	,389	,663	,500	,137
	N	20	20	20	20	20	20	16	20	20
War etwas besonders an den Fenstern im Bereich überm Tunnel?	Korrelationskoeffizient	-,325	-,038	,151	,061	,110	,113	,319	-,355	-,091
	Sig. (2-seitig)	,079	,857	,472	,750	,557	,565	,143	,046	,637
	N	20	20	20	20	20	20	16	20	20
Welche Farbe hatte der Türrahmen in der Wand mit den vier Säulen?	Korrelationskoeffizient	,200	,095	-,076	,165	,313	-,164	-,441	,158	-,014
	Sig. (2-seitig)	,282	,650	,717	,390	,094	,403	,043	,374	,941
	N	20	20	20	20	20	20	16	20	20
Welches Symbol war im Seitentunnel zu sehen?	Korrelationskoeffizient	,013	-,244	,112	-,385	-,186	,098	,398	,149	-,438
	Sig. (2-seitig)	,945	,242	,589	,043	,315	,614	,068	,397	,022
	N	20	20	20	20	20	20	16	20	20

Kendall-Tau-b

Figure A.9: TV

A.1.4 Hypothesis RQ 3d - Prior gaming experiences significantly influences 2D distance judging

Kendall-Tau-b

		Was ist dein Lieblingsspiel / Spielreihe? -> Genre	Was ist dein Lieblingsgenre? (Action)	Was ist dein Lieblingsgenre? (Action-Adventure)	Was ist dein Lieblingsgenre? (Adventure)	Was ist dein Lieblingsgenre? (Role Playing Game)	Was ist dein Lieblingsgenre? (Simulation)	Was ist dein Lieblingsgenre? (Strategy)	Was ist dein Lieblingsgenre? (NoPreferances)	Was ist dein Lieblingsgenre? (NotApplicable)	Mit welchem Spiel/Spielreihe hast du am meisten Zeit verbracht? -> Genre	An wievielen Wochentagen hast du Videospiele während deiner Schulzeit gespielt?	Wie lange an einem Tag hast du im Schnitt maximal wärend deiner Schulzeit gespielt?	An wievielen Wochentagen spielst du Videospiel aktuell?	Wie lange an einem Tag spielst du im Schnitt maximal aktuell?	Wieviele richtige Spiele hast du dieses Jahr gespielt?	Hast du schonmal eine Bildschirmbrille ausprobiert? (Klassiert)	Was studierst du? (Bezug zu Virtualität)
Was ist dein Lieblingsspiel / Spielreihe? -> Genre	Korrelationskoeffizient	1,000	-,416	-,142	,000	-,334	-,055	,017	,311	,264	,348	-,497	-,399	-,318	-,300	-,479	-,161	-,416
	Sig. (2-seitig)		,026	,445	1,000	,074	,770	,927	,096	,158	,040	,003	,017	,059	,081	,004	,388	,026
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Was ist dein Lieblingsgenre? (Action)	Korrelationskoeffizient	-,416	1,000	-,194	-,145	-,060	-,011	-,397	-,155	-,107	-,099	,128	,142	,014	,000	,165	-,060	,434
	Sig. (2-seitig)	,026		,352	,487	,773	,960	,057	,458	,608	,600	,489	,444	,941	1,000	,367	,773	,038
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Was ist dein Lieblingsgenre? (Action-Adventure)	Korrelationskoeffizient	-,142	-,194	1,000	,267	,158	,116	-,293	-,114	-,079	-,356	-,074	,058	,195	,236	-,040	,411	,319
	Sig. (2-seitig)	,445	,352		,200	,449	,577	,160	,585	,705	,059	,688	,754	,298	,218	,825	,049	,126
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Was ist dein Lieblingsgenre? (Adventure)	Korrelationskoeffizient	,000	-,145	,267	1,000	,059	,290	,000	-,213	-,147	-,262	-,093	-,221	,012	,221	,000	,237	,239
	Sig. (2-seitig)	1,000	,487	,200		,777	,164	1,000	,307	,480	,165	,616	,233	,949	,249	1,000	,257	,252
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Was ist dein Lieblingsgenre? (Role Playing Game)	Korrelationskoeffizient	-,334	-,060	,158	,059	1,000	-,060	,151	-,277	-,192	-,271	,345	,320	,321	,226	,446	,161	,269
	Sig. (2-seitig)	,074	,773	,449	,777		,773	,469	,183	,358	,151	,062	,085	,087	,237	,015	,440	,198
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Was ist dein Lieblingsgenre? (Simulation)	Korrelationskoeffizient	-,055	-,011	,116	,290	-,060	1,000	,238	-,155	-,107	,205	-,114	-,176	,180	,206	,046	,146	,225
	Sig. (2-seitig)	,770	,960	,577	,164	,773		,253	,458	,608	,277	,536	,343	,338	,281	,801	,484	,280
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Was ist dein Lieblingsgenre? (Strategy)	Korrelationskoeffizient	,017	-,397	-,293	,000	,151	,238	1,000	-,234	-,162	,160	,152	,108	-,070	,042	,039	,151	-,044
	Sig. (2-seitig)	,927	,057	,160	1,000	,469	,253		,263	,439	,396	,410	,561	,711	,827	,832	,469	,834
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Was ist dein Lieblingsgenre? (NoPreferances)	Korrelationskoeffizient	,311	-,155	-,114	-,213	-,277	-,155	-,234	1,000	-,063	,104	-,148	-,139	-,152	-,105	-,165	,025	-,051
	Sig. (2-seitig)	,096	,458	,585	,307	,183	,458	,263		,763	,582	,423	,453	,417	,585	,367	,904	,807
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Was ist dein Lieblingsgenre? (NotApplicable)	Korrelationskoeffizient	,264	-,107	-,079	-,147	-,192	-,107	-,162	-,063	1,000	,301	-,273	-,275	-,211	-,217	-,241	-,192	-,247
	Sig. (2-seitig)	,158	,608	,705	,480	,358	,608	,439	,763		,110	,139	,139	,261	,257	,187	,358	,237
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Mit welchem Spiel/Spielreihe hast du am meisten Zeit verbracht? -> Genre	Korrelationskoeffizient	,348	-,099	-,356	-,262	-,271	,205	,160	,104	,301	1,000	-,077	-,154	-,149	-,210	-,177	-,150	-,343
	Sig. (2-seitig)	,040	,600	,059	,165	,151	,277	,396	,582	,110		,647	,359	,382	,225	,285	,427	,068
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
An wievielen Wochentagen hast du Videospiele während deiner Schulzeit gespielt?	Korrelationskoeffizient	-,497	,128	-,074	-,093	,345	-,114	,152	-,148	-,273	-,077	1,000	,708	,216	,177	,379	,318	,161
	Sig. (2-seitig)	,003	,489	,688	,616	,062	,536	,410	,423	,139	,647		,000	,194	,297	,020	,085	,385
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Wie lange an einem Tag hast du im Schnitt maximal wärend deiner Schulzeit gespielt?	Korrelationskoeffizient	-,399	,142	,058	-,221	,320	-,176	,108	-,139	-,275	-,154	,708	1,000	,360	,242	,470	,232	,267
	Sig. (2-seitig)	,017	,444	,754	,233	,085	,343	,561	,453	,139	,359	,000		,032	,156	,004	,212	,150
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
An wievielen Wochentagen spielst du Videospiel aktuell?	Korrelationskoeffizient	-,318	,014	,195	,012	,321	,180	-,070	-,152	-,211	-,149	,216	,360	1,000	,603	,724	-,107	,125
	Sig. (2-seitig)	,059	,941	,298	,949	,087	,338	,711	,417	,261	,382	,194	,032		,000	,000	,568	,504
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Wie lange an einem Tag spielst du im Schnitt maximal aktuell?	Korrelationskoeffizient	-,300	,000	,236	,221	,226	,206	,042	-,105	-,217	-,210	,177	,242	,603	1,000	,508	-,006	,275
	Sig. (2-seitig)	,081	1,000	,218	,249	,237	,281	,827	,585	,257	,225	,297	,156	,000		,003	,976	,150
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Wieviele richtige Spiele hast du dieses Jahr gespielt?	Korrelationskoeffizient	-,479	,165	-,040	,000	,446	,046	,039	-,165	-,241	-,177	,379	,470	,724	,508	1,000	-,054	,179
	Sig. (2-seitig)	,004	,367	,825	1,000	,015	,801	,832	,367	,187	,285	,020	,004	,000	,003		,769	,327
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Hast du schonmal eine Bildschirmbrille ausprobiert? (Klassiert)	Korrelationskoeffizient	-,161	-,060	,411	,237	,161	,146	,151	,025	-,192	-,150	,318	,232	-,107	-,006	-,054	1,000	,269
	Sig. (2-seitig)	,388	,773	,049	,257	,440	,484	,469	,904	,358	,427	,085	,212	,568	,976	,769		,198
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Was studierst du? (Bezug zu Virtualität)	Korrelationskoeffizient	-,416	,434	,319	,239	,269	,225	-,044	-,051	-,247	-,343	,161	,267	,125	,275	,179	,269	1,000
	Sig. (2-seitig)	,026	,038	,126	,252	,198	,280	,834	,807	,237	,068	,385	,150	,504	,150	,327	,198	
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Wie ist der Abstand zwischen den Bodenleuchten in m? (Abweichung)	Korrelationskoeffizient	-,122	,242	-,165	,174	-,027	,350	,118	-,405	-,109	,005	,172	,138	,225	,154	,270	,077	,094
	Sig. (2-seitig)	,463	,192	,373	,349	,883	,059	,523	,029	,555	,979	,297	,404	,178	,365	,098	,679	,612
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Wie hoch ist der Tunnel in der Mitte in m? (Abweichung)	Korrelationskoeffizient	,013	,112	,211	,364	,016	,238	-,122	-,282	-,081	-,217	-,228	-,089	,056	,018	,087	-,016	,125
	Sig. (2-seitig)	,938	,539	,249	,046	,930	,193	,505	,124	,659	,190	,161	,585	,732	,915	,589	,930	,493
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Wie breit ist der Tunnel in m? (Abweichung)	Korrelationskoeffizient	,088	,081	-,333	-,012	-,050	,102	,159	,020	-,248	-,050	-,074	-,100	,134	,087	,208	-,227	-,173
	Sig. (2-seitig)	,598	,661	,073	,950	,789	,584	,391	,915	,182	,766	,656	,546	,425	,611	,203	,223	,351
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Wie breit ist der Pfad zum Tunnel in m? (Abweichung)	Korrelationskoeffizient	-,173	,403	-,318	,000	-,039	,055	,046	-,110	-,305	-,073	,309	,149	-,009	,042	,171	,050	,135
	Sig. (2-seitig)	,301	,030	,087	1,000	,834	,769	,805	,553	,101	,664	,061	,369	,957	,808	,296	,788	,468
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

Figure A.10: HMD

Figure A.11: Real

Kendall-Tau-b

		Was ist dein Lieblingsspiel / Spielreihe? -> Genre	Was ist dein Lieblingsgenre? (Action)	Was ist dein Lieblingsgenre? (Action-Adventure)	Was ist dein Lieblingsgenre? (Adventure)	Was ist dein Lieblingsgenre? (Role Playing Game)	Was ist dein Lieblingsgenre? (Simulation)	Was ist dein Lieblingsgenre? (Strategy)	Was ist dein Lieblingsgenre? (NoPreferances)	Was ist dein Lieblingsgenre? (NotApplicable)	Mit welchem Spiel/Spielreihe hast du am meisten Zeit verbracht? -> Genre	An wievielen Wochentagen hast du Videospiele während deiner Schulzeit gespielt?	Wie lange an einem Tag hast du im Schnitt maximal wärend deiner Schulzeit gespielt?	An wievielen Wochentagen spielst du Videospiel aktuell?	Wie lange an einem Tag spielst du im Schnitt maximal aktuell?	Wieviele richtige Spiele hast du dieses Jahr gespielt?	Hast du schonmal eine Bildschirmbrille ausprobiert? (Klassiert)	Was studierst du? (Bezug zu Virtualität)
Was ist dein Lieblingsspiel / Spielreihe? -> Genre	Korrelationskoeffizient	1,000	-,056	-,070	-,057	-,098	,176	-,403	,187	.	,272	-,148	,159	-,019	,034	-,165	-,080	-,067
	Sig. (2-seitig)	.	,784	,733	,781	,633	,393	,050	,364	.	,164	,425	,388	,917	,858	,358	,696	,744
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Was ist dein Lieblingsgenre? (Action)	Korrelationskoeffizient	-,056	1,000	-,201	,082	,328	-,058	,179	-,302	.	-,189	,517*	,255	,696**	,474*	,453*	-,394	,099
	Sig. (2-seitig)	,784	.	,381	,721	,152	,800	,435	,189	.	,386	,012	,213	,001	,026	,023	,086	,668
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Was ist dein Lieblingsgenre? (Action-Adventure)	Korrelationskoeffizient	-,070	-,201	1,000	-,153	-,102	,000	-,367	-,167	.	,078	-,030	-,258	-,189	-,236	-,143	-,050	-,140
	Sig. (2-seitig)	,733	,381	.	,505	,656	1,000	,110	,468	.	,719	,884	,208	,355	,268	,473	,827	,542
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Was ist dein Lieblingsgenre? (Adventure)	Korrelationskoeffizient	-,057	,082	-,153	1,000	,250	-,236	-,171	-,272	.	-,027	,016	-,016	,252	,096	,312	,123	,343
	Sig. (2-seitig)	,781	,721	,505	.	,276	,304	,456	,235	.	,900	,937	,937	,218	,651	,118	,592	,135
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Was ist dein Lieblingsgenre? (Role Playing Game)	Korrelationskoeffizient	-,098	,328	-,102	,250	1,000	,000	,171	-,408	.	-,274	,434*	,437*	,487*	,446*	,437*	-,123	,229
	Sig. (2-seitig)	,633	,152	,656	,276	.	1,000	,456	,075	.	,208	,035	,033	,017	,036	,029	,592	,319
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Was ist dein Lieblingsgenre? (Simulation)	Korrelationskoeffizient	,176	-,058	,000	-,236	,000	1,000	,303	-,192	.	,062	,037	,183	-,046	,050	-,124	,058	-,081
	Sig. (2-seitig)	,393	,800	1,000	,304	1,000	.	,187	,402	.	,776	,857	,371	,822	,816	,536	,800	,725
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Was ist dein Lieblingsgenre? (Strategy)	Korrelationskoeffizient	-,403	,179	-,367	-,171	,171	,303	1,000	-,245	.	-,150	,152	,091	,108	,135	,184	,242	,308
	Sig. (2-seitig)	,050	,435	,110	,456	,456	,187	.	,286	.	,491	,463	,655	,596	,526	,356	,291	,179
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Was ist dein Lieblingsgenre? (NoPreferances)	Korrelationskoeffizient	,187	-,302	-,167	-,272	-,408	-,192	-,245	1,000	.	,522*	-,455*	-,397	-,398	-,400	-,408*	-,369	-,327
	Sig. (2-seitig)	,364	,189	,468	,235	,075	,402	,286	.	.	,017	,027	,053	,052	,060	,041	,108	,154
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Was ist dein Lieblingsgenre? (NotApplicable)	Korrelationskoeffizient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	Sig. (2-seitig)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Mit welchem Spiel/Spielreihe hast du am meisten Zeit verbracht? -> Genre	Korrelationskoeffizient	,272	-,189	,078	-,027	-,274	,062	-,150	,522*	.	1,000	-,295	-,312	-,256	-,307	-,274	,072	,075
	Sig. (2-seitig)	,164	,386	,719	,900	,208	,776	,491	,017	.	.	,133	,108	,187	,129	,150	,741	,730
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
An wievielen Wochentagen hast du Videospiele während deiner Schulzeit gespielt?	Korrelationskoeffizient	-,148	,517*	-,030	,016	,434*	,037	,152	-,455*	.	-,295	1,000	,446*	,652**	,551**	,553**	,065	,259
	Sig. (2-seitig)	,425	,012	,884	,937	,035	,857	,463	,027	.	,133	.	,016	,000	,004	,002	,754	,210
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Wie lange an einem Tag hast du im Schnitt maximal wärend deiner Schulzeit gespielt?	Korrelationskoeffizient	,159	,255	-,258	-,016	,437*	,183	,091	-,397	.	-,312	,446*	1,000	,385*	,381*	,418*	,271	,155
	Sig. (2-seitig)	,388	,213	,208	,937	,033	,371	,655	,053	.	,108	,016	.	,035	,045	,019	,185	,447
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
An wievielen Wochentagen spielst du Videospiel aktuell?	Korrelationskoeffizient	-,019	,696**	-,189	,252	,487*	-,046	,108	-,398	.	-,256	,652**	,385*	1,000	,648**	,669**	-,168	,189
	Sig. (2-seitig)	,917	,001	,355	,218	,017	,822	,596	,052	.	,187	,000	,035	.	,001	,000	,411	,354
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Wie lange an einem Tag spielst du im Schnitt maximal aktuell?	Korrelationskoeffizient	,034	,474*	-,236	,096	,446*	,050	,135	-,400	.	-,307	,551**	,381*	,648**	1,000	,708**	-,034	,300
	Sig. (2-seitig)	,858	,026	,268	,651	,036	,816	,526	,060	.	,129	,004	,045	,001	.	,000	,871	,159
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Wieviele richtige Spiele hast du dieses Jahr gespielt?	Korrelationskoeffizient	-,165	,453*	-,143	,312	,437*	-,124	,184	-,408*	.	-,274	,553**	,418*	,669**	,708**	1,000	,123	,428*
	Sig. (2-seitig)	,358	,023	,473	,118	,029	,536	,356	,041	.	,150	,002	,019	,000	,000	.	,538	,032
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Hast du schonmal eine Bildschirmbrille ausprobiert? (Klassiert)	Korrelationskoeffizient	-,080	-,394	-,050	,123	-,123	,058	,242	-,369	.	,072	,065	,271	-,168	-,034	,123	1,000	,464*
	Sig. (2-seitig)	,696	,086	,827	,592	,592	,800	,291	,108	.	,741	,754	,185	,411	,871	,538	.	,043
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Was studierst du? (Bezug zu Virtualität)	Korrelationskoeffizient	-,067	,099	-,140	,343	,229	-,081	,308	-,327	.	,075	,259	,155	,189	,300	,428*	,464*	1,000
	Sig. (2-seitig)	,744	,668	,542	,135	,319	,725	,179	,154	.	,730	,210	,447	,354	,159	,032	,043	.
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Was ist der Abstand zwischen den Bodenleuchten in m? (Abweichung)	Korrelationskoeffizient	-,094	-,063	-,275	-,040	-,345	-,118	,082	,052	.	,056	-,303	-,025	-,156	-,061	-,114	,229	,220
	Sig. (2-seitig)	,606	,756	,176	,844	,090	,562	,685	,797	.	,771	,099	,891	,390	,748	,521	,260	,279
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Wie hoch ist der Tunnel in der Mitte in m? (Abweichung)	Korrelationskoeffizient	,006	-,308	,010	,063	-,149	-,354	-,249	-,115	.	-,096	-,290	-,091	-,256	-,256	-,229	,347	-,043
	Sig. (2-seitig)	,973	,124	,962	,754	,458	,077	,213	,566	.	,614	,109	,611	,153	,169	,192	,083	,830
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Wie breit ist der Tunnel im m? (Abweichung)	Korrelationskoeffizient	,032	-,255	-,030	-,227	-,267	-,064	-,075	-,079	.	-,270	-,025	,075	-,082	-,143	-,139	,287	-,022
	Sig. (2-seitig)	,863	,213	,885	,269	,192	,754	,715	,699	.	,166	,890	,681	,654	,454	,437	,162	,914
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Wie breit ist der Pfad zum Tunnel in m? (Abweichung)	Korrelationskoeffizient	-,208	-,184	-,162	-,039	-,086	-,035	,136	-,292	.	-,327	,073	,091	-,067	-,020	-,047	,314	,299
	Sig. (2-seitig)	,247	,355	,416	,845	,668	,860	,495	,142	.	,084	,683	,612	,708	,916	,789	,115	,134
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

Figure A.12: TV

A.1.5 Hypothesis RQ 3e - Prior gaming experiences significantly influences 3D Space judging

Figure A.13: HMD

Figure A.14: Real

Figure A.15: TV

A.1.6 Hypothesis RQ 3f - Prior gaming experiences significantly influences peripheral perception

APPEN

Figure A.16: HMD

Kendalls Tau-b

Variable	Statistik	Was ist dein Lieblingsspiel / Spielreihe? -> Genre	Was ist dein Lieblingsgenre? (Action)	Was ist dein Lieblingsgenre? (Action-Adventure)	Was ist dein Lieblingsgenre? (Adventure)	Was ist dein Lieblingsgenre? (Role Playing Game)	Was ist dein Lieblingsgenre? (Simulation)	Was ist dein Lieblingsgenre? (Strategy)	Was ist dein Lieblingsgenre? (NoPreferances)	Was ist dein Lieblingsgenre? (NotApplicable)	Mit welchem Spiel/Spielreihe hast du am meisten Zeit verbracht? -> Genre	An wievielen Wochentagen hast du Videospiele während deiner Schulzeit gespielt?	Wie lange an einem Tag hast du im Schnitt maximal wärend deiner Schulzeit gespielt?	An wievielen Wochentagen spielst du Videospiel aktuell?	Wie lange an einem Tag spielst du im Schnitt maximal aktuell?	Wieviele richtige Spiele hast du dieses Jahr gespielt?	Hast du schonmal eine Bildschirmbrille ausprobiert? (Klassiert)	Was studierst du? (Bezug zu Virtualität)
Was ist dein Lieblingsspiel / Spielreihe? -> Genre	Korrelationskoeffizient	1,000	-,533	-,164	-,332	-,125	,083	-,136	,310	,591	,894	-,328	-,147	-,471	-,336	-,290	.	.
	Sig. (2-seitig)		,024	,487	,160	,598	,725	,566	,189	,012	,000	,121	,493	,034	,130	,191	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Was ist dein Lieblingsgenre? (Action)	Korrelationskoeffizient	-,533	1,000	,092	-,078	-,078	-,389	-,218	-,218	-,277	-,464	,505	,267	,501	,372	,343	.	.
	Sig. (2-seitig)	,024		,720	,763	,763	,132	,398	,398	,283	,050	,029	,255	,039	,125	,157	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Was ist dein Lieblingsgenre? (Action-Adventure)	Korrelationskoeffizient	-,164	,092	1,000	,367	,713	,022	,787	-,182	-,231	-,349	,560	,476	,020	,131	,453	.	.
	Sig. (2-seitig)	,487	,720		,155	,006	,933	,002	,482	,371	,141	,015	,042	,935	,588	,061	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Was ist dein Lieblingsgenre? (Adventure)	Korrelationskoeffizient	-,332	-,078	,367	1,000	,127	,127	,153	-,255	-,324	-,238	,162	,277	,385	,205	,244	.	.
	Sig. (2-seitig)	,160	,763	,155		,622	,622	,554	,324	,210	,316	,483	,237	,113	,397	,314	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Was ist dein Lieblingsgenre? (Role Playing Game)	Korrelationskoeffizient	-,125	-,078	,713	,127	1,000	,418	,561	-,255	-,324	-,238	,310	,443	-,151	,253	,168	.	.
	Sig. (2-seitig)	,598	,763	,006	,622		,105	,030	,324	,210	,316	,179	,059	,535	,297	,488	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Was ist dein Lieblingsgenre? (Simulation)	Korrelationskoeffizient	,083	-,389	,022	,127	,418	1,000	,153	-,255	-,324	-,028	,013	,360	-,117	,142	-,092	.	.
	Sig. (2-seitig)	,725	,132	,933	,622	,105		,554	,324	,210	,906	,953	,124	,630	,557	,706	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Was ist dein Lieblingsgenre? (Strategy)	Korrelationskoeffizient	-,136	-,218	,787	,153	,561	,153	1,000	-,143	-,182	-,392	,378	,271	-,234	-,022	,321	.	.
	Sig. (2-seitig)	,566	,398	,002	,554	,030	,554		,580	,482	,098	,101	,246	,334	,927	,185	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Was ist dein Lieblingsgenre? (NoPreferances)	Korrelationskoeffizient	,310	-,218	-,182	-,255	-,255	-,255	-,143	1,000	-,182	,333	-,378	-,388	-,234	-,265	-,300	.	.
	Sig. (2-seitig)	,189	,398	,482	,324	,324	,324	,580		,482	,160	,101	,098	,334	,273	,217	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Was ist dein Lieblingsgenre? (NotApplicable)	Korrelationskoeffizient	,591	-,277	-,231	-,324	-,324	-,324	-,182	-,182	1,000	,598	-,208	-,279	-,298	-,337	-,073	.	.
	Sig. (2-seitig)	,012	,283	,371	,210	,210	,210	,482	,482		,012	,367	,233	,220	,163	,765	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Mit welchem Spiel/Spielreihe hast du am meisten Zeit verbracht? -> Genre	Korrelationskoeffizient	,894	-,464	-,349	-,238	-,238	-,028	-,392	,333	,598	1,000	-,436	-,234	-,386	-,243	-,317	.	.
	Sig. (2-seitig)	,000	,050	,141	,316	,316	,906	,098	,160	,012		,040	,278	,084	,275	,155	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
An wievielen Wochentagen hast du Videospiele während deiner Schulzeit gespielt?	Korrelationskoeffizient	-,328	,505	,560	,162	,310	,013	,378	-,378	-,208	-,436	1,000	,708	,335	,398	,713	.	.
	Sig. (2-seitig)	,121	,029	,015	,483	,179	,953	,101	,101	,367	,040		,001	,124	,066	,001	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Wie lange an einem Tag hast du im Schnitt maximal wärend deiner Schulzeit gespielt?	Korrelationskoeffizient	-,147	,267	,476	,277	,443	,360	,271	-,388	-,279	-,234	,708	1,000	,267	,600	,523	.	.
	Sig. (2-seitig)	,493	,255	,042	,237	,059	,124	,246	,098	,233	,278	,001		,226	,006	,018	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
An wievielen Wochentagen spielst du Videospiel aktuell?	Korrelationskoeffizient	-,471	,501	,020	,385	-,151	-,117	-,234	-,234	-,298	-,386	,335	,267	1,000	,581	,534	.	.
	Sig. (2-seitig)	,034	,039	,935	,113	,535	,630	,334	,334	,220	,084	,124	,226		,011	,019	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Wie lange an einem Tag spielst du im Schnitt maximal aktuell?	Korrelationskoeffizient	-,336	,372	,131	,205	,253	,142	-,022	-,265	-,337	-,243	,398	,600	,581	1,000	,517	.	.
	Sig. (2-seitig)	,130	,125	,588	,397	,297	,927	,273	,163	,275	,066	,006	,011		,023	.	.	
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Wieviele richtige Spiele hast du dieses Jahr gespielt?	Korrelationskoeffizient	-,290	,343	,453	,244	,168	-,092	,321	-,300	-,073	-,317	,713	,523	,534	,517	1,000	.	.
	Sig. (2-seitig)	,191	,157	,061	,314	,488	,706	,185	,217	,765	,155	,001	,018	,019	,023		.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Hast du schonmal eine Bildschirmbrille ausprobiert? (Klassiert)	Korrelationskoeffizient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	Sig. (2-seitig)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Was studierst du? (Bezug zu Virtualität)	Korrelationskoeffizient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	Sig. (2-seitig)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gab es nur in den Boden gepflanzte Bäume im Schloßhof?	Korrelationskoeffizient	-,331	-,107	-,060	,251	,351	,351	,351	-,281	-,281	-,358	-,219	,025	,204	,523	,450	,154	.
	Sig. (2-seitig)	,151	,670	,813	,319	,163	,163	,163	,264	,264	,156	,345	,912	,373	,027	,057	,514	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Zu wieviele waren die Schießscharten der Kurtinenwand gruppiert? (Abweichung)	Korrelationskoeffizient	-,274	,037	,102	,291	-,017	,051	,192	-,144	-,142	-,224	,330	,352	,252	,372	,532	.	.
	Sig. (2-seitig)	,228	,882	,681	,240	,945	,836	,438	,561	,565	,325	,136	,118	,279	,110	,022	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Was ist die Farbe der Baumkübel?	Korrelationskoeffizient	-,183	,020	-,022	,241	-,019	-,259	-,026	,000	,000	,000	-,165	-,169	-,307	-,113	-,249	.	.
	Sig. (2-seitig)	,421	,936	,929	,333	,941	,297	,917	1,000	1,000	1,000	,459	,454	,190	,629	,287	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
War etwas besonders an den Fenstern im Bereich überm Tunnel?	Korrelationskoeffizient	,243	-,031	-,224	-,305	,044	-,247	-,326	,041	,328	,347	-,097	-,089	-,013	-,139	-,024	.	.
	Sig. (2-seitig)	,271	,897	,352	,205	,856	,305	,176	,866	,174	,118	,653	,686	,953	,540	,914	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Welche Farbe hatte der Türrahmen in der Wand mit den vier Säulen?	Korrelationskoeffizient	,010	-,115	-,432	,013	-,067	,445	-,378	-,227	-,048	,104	-,110	-,113	-,112	,012	-,226	.	.
	Sig. (2-seitig)	,961	,617	,061	,953	,770	,054	,102	,326	,835	,626	,596	,591	,608	,957	,297	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0
Welches Symbol war im Seitentunnel zu sehen?	Korrelationskoeffizient	,369	-,271	-,225	-,316	-,021	-,021	-,177	,325	,200	,405	-,469	-,481	-,291	-,329	-,371	.	.
	Sig. (2-seitig)	,112	,285	,374	,212	,934	,934	,484	,199	,429	,082	,038	,036	,222	,165	,118	.	.
	N	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	0

Figure A.17: Real

Figure A.18: TV

A.2 How the spatial and peripheral questionnaire questions map to real locations

- Main Court

Figure A.19: Spatial: height of well

Figure A.20: Spatial: width of Kurtine

Figure A.21: Peripheral: types of tree in courtyard

- Rheinbastion

Figure A.22: Spatial: height of tree in front of tunnel

Figure A.23: Spatial: height and width of wall with arrow slits + Peripheral: size of arrowslits sets

Figure A.24: Peripheral: colour of treebuckets

- Area over tunnel

Figure A.25: Spatial: height and width of 4 column wall + Peripheral: differences in types of windows and colour of door frame

- Tunnel

Figure A.26: Spatial: distance between floor lights

Figure A.27: Spatial: overall height and width of tunnel

Figure A.28: Peripheral: symbol in side tunnel

- Osthof

Figure A.29: Spatial: width of path to tunnel

Figure A.30: Spatial: Height of opposite wall

A.3 How the spatial and peripheral questionnaire questions map to virtual locations

- Main Court

Figure A.31: Spatial: height of well

Figure A.32: Spatial: width of Kurtine

Figure A.33: Peripheral: types of tree in courtyard

- Rheinbastion

Figure A.34: Spatial: height of tree in front of tunnel

Figure A.35: Spatial: height and width of wall with arrow slits + Peripheral: size of arrowslits sets

Figure A.36: Peripheral: colour of treebuckets

- Area over tunnel

Figure A.37: Spatial: height and width of 4 column wall + Peripheral: differences in types of windows and colour of door frame
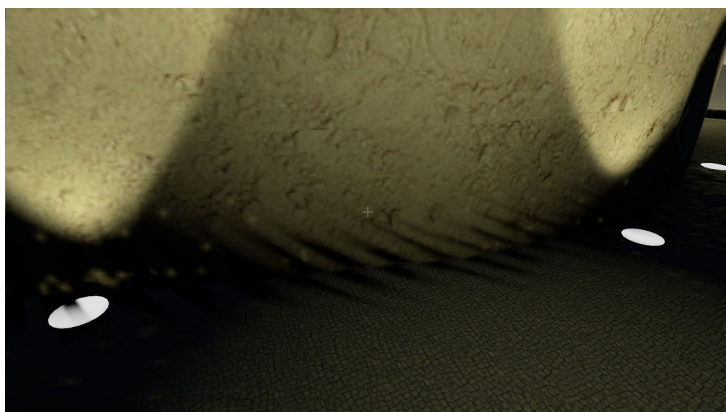
- Tunnel

Figure A.38: Spatial: distance between floor lights

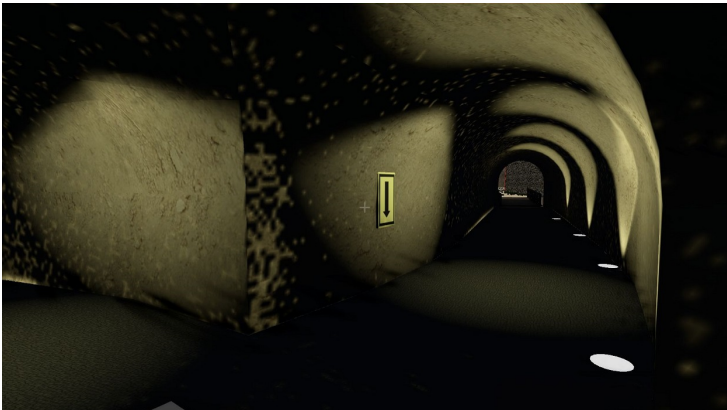**Figure A.39:** Spatial: overall height and width of tunnel

Figure A.40: Peripheral: symbol in side tunnel

- Osthof

Figure A.41: Spatial: width of path to tunnel

Figure A.42: Spatial: Height of opposite wall

A.4 Experiment Survey

Questionnair about perception of fortress visit
* Erforderlich

Part 1 - Before Test

Part 1.1 - Prior real experiences

1. **In what type of city did you spent most of your Childhood?** *
Markieren Sie nur ein Oval.

- ( ) Metropolis > 5 Million
- ( ) Capital City 3 - 4.9 Million
- ( ) Very Large City 1 - 2.9 Million
- ( ) Large City 500k - 999k
- ( ) City 100k - 499k
- ( ) Big Town 50k - 99k
- ( ) Town 20k - 49k
- ( ) Big Village 10k - 19k
- ( ) Village 5k - 9k
- ( ) Municipality < 4k
- ( ) Sonstiges: _____

2. **Have you been part of boy scouts or similar as a kid?** *
Similar: Kindergarten Forest Camp
Markieren Sie nur ein Oval.

- ( ) Yes
- ( ) No
- ( ) Don't know

3. **Did you complete any form of military training?** *
Markieren Sie nur ein Oval.

- ( ) Yes
- ( ) No
- ( ) Don't know

4. **As a kid, starting from what age did you go alone/unaccompanied to regular places like preschool/kindergarten/school?** *

_____

5. **As a kid, starting from what age did you go alone/unaccompanied to irregular places like friends?** *
Make the difference between regular und irregular clear, Age might be hard to remember => class grade is okay as well

_____

6. **What mode of transport have you commonly used before you got a driver's license?** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
Based on external route (bus, subway, train, tram, parents)	( )	( )	( )	( )	( )	Based on own route (bike, walk)

7. **What mode of transport do you commenly use since you got a driver's license?**
If not applicable because no driver's license: leave question empty
Markieren Sie nur ein Oval.

	1	2	3	4	5	
Based on external route (bus, subway, train, tram, parents)	( )	( )	( )	( )	( )	Based on own route (car, scooter, bike, walk)

Part 1.2 - Prior virtual experiences

8. **What's the name of your favourite game/series?** *

_____

9. **What's your favourite Genre?** *
Wählen Sie alle zutreffenden Antworten aus.

- [ ] Action
- [ ] Action: Shooter
- [ ] Action-Adventure
- [ ] Adventure
- [ ] Role Playing Game
- [ ] Simulation
- [ ] Simulation: Sport
- [ ] Strategy
- [ ] Multiplayer online Game
- [ ] No Preferances
- [ ] Not applicable

10. **What Game/Series did you spent the most time on?** *

_____

11. **On how many days in the week did you play Videogames during your time in school?** *

_____

12. **How much time, per day on average, did you spent for playing videogames during school days?** *

Markieren Sie nur ein Oval.

- ( ) 0h
- ( ) < 1h
- ( ) 1 - 2h
- ( ) 2 - 3h
- ( ) 3 - 4h
- ( ) 4 - 5h
- ( ) 5 - 6h
- ( ) >6h

13. **On how many days in the week do you play Videogames these days?** *

If less then once a week => use fractions

_____

14. **How much time, per day on average, do you spent for one gaming session these days?** *

Markieren Sie nur ein Oval.

- ( ) 0h
- ( ) < 1h
- ( ) 1 - 2h
- ( ) 2 - 3h
- ( ) 3 - 4h
- ( ) 4 - 5h
- ( ) 5 - 6h
- ( ) >6h

15. **How many proper games have you played this year?** *

Proper as in no flash/Facebook games, 2015&2016

_____

16. **Did you ever wore an Head Mounted Display (HMD) ?** *

Wählen Sie alle zutreffenden Antworten aus.

- [ ] No
- [ ] Yes, unsure which one
- [ ] Yes, Oculus Rift DK 1
- [ ] Yes, Oculus Rift DK 2
- [ ] Yes, Samsung Gear VR
- [ ] Yes, HTC Vive DK 1
- [ ] Sonstiges: _____

Part 2 - During Test

Don't leave the spot, Only use own body parts (Arm, Hands, ...)
No Phone & Gadgets at all allowed.
Don't talk to each other
Please state all heights until the end of the wall and not until a ledge

VR Additional Cues: Length & Width of Plattform = 3*3m, 1m Ref Cross

Part 2.1 - Questions for Main Court

Hints:
---Wallstones next to protruded columns height = 0.4m ;
---4 Cornerstones of Cafe height = 1.5m;
---Kurtine Gate = 4m wide & 5m high
---Spheres next to well height = 1.6m

17. **What is the angular position of the well? (Stop1)** *

Measured based on N=0, E=90, S=180, W=270, Round to nearest 5

_____

18. **How high is the well in m?** *

_____

19. **What is the width of the kurtine in m?** *

_____

Part 2.2 Questions for Rheinbastion

Hints:
---Height 4 Cornerstones = 1.5m;
---Handrail/fence height = 1m;
---Arrowslits width = 0.5m

20. **Where there only planted trees in the main court?** *
Markieren Sie nur ein Oval.

- ( ) Yes
- ( ) No
- ( ) Don't know

21. **What is the angular position of the well? (Stop2)** *
What is the angular position of the well?
Measured based on N=0, E=90, S=180, W=270, Round to nearest 5

22. **How high is the smaller tree in front of the tunnel in m?** *

23. **How high is the wall with the arrowslits in m?** *

24. **How wide is the wall with the arrowslits in m?** *

Part 2.3 - Questions for area over Tunnel

Hints:
---4 Column wall 4 stones height = 1.5m;
---Window frame width = 1m

25. **How large where the sets of arrowslits on the kurtine wall?** *
Grouped in Sets of 2/3/4/...

26. **What colour are the treebuckets?** *

27. **What is the angular position of the well? (Stop3)** *
Measured based on N=0, E=90, S=180, W=270, Round to nearest 5

28. **How high is the wall with the 4 Columns in m?** *

29. **How wide is the wall with the 4 Columns in m?** *

Part 2.3b - Influence on Emotions

Based on what we've seen so far

30. **Would you recommend a visit to a close friend?** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
No, not at all	( )	( )	( )	( )	( )	Yes, definitely

31. **Is it worth a trip with your business colleagues / class mates?** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
No, not at all	( )	( )	( )	( )	( )	Yes, definitely

32. **Are you interested in exploring the rest of the afterwards fortress?** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
No, not at all	( )	( )	( )	( )	( )	Yes, definitely

33. **Did you expect the fortress to have so many details?** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
No, not at all	( )	( )	( )	( )	( )	Yes, definitely

34. **Do you think time flew by while doing the test?** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
No, not at all	( )	( )	( )	( )	( )	Yes, definitely

35. **Does it bother/irritate you how big the fortress is?** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
No, not at all	( )	( )	( )	( )	( )	Yes, definitely

36. **Are you feeling motion sick?** *

Feeling in stomach similar to sea / travel sickness
Markieren Sie nur ein Oval.

	1	2	3	4	5	
No, not at all	( )	( )	( )	( )	( )	Yes, definitely

Part 2.4 - Questions for Tunnel

Hints:
---Width von Side Tunnel Gap = 4.8m
---Platform not 3*3!

37. **Was there something special about the windows in the area over the tunnel?** *

38. **What colour had the door frame of the 4 column wall?** *

39. **Do you think 1st / 2nd Grade school children (6-8) would be scared of the tunnel?** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
No, not at all	( )	( )	( )	( )	( )	Yes, definitely

40. **What is the angular position of the well? (Stop4)** *

Measured based on N=0, E=90, S=180, W=270, Round to nearest 5

41. **What's the distance between the Floor lights in m?** *

Nahe an der Plattform und rechts davon (#4 & #6)

42. **How high is the tunnel in the middle in m?** *

43. **How wide is the tunnel in m?** *

Part 2.5 - Questions for Osthof

Hints:
---4 Cornerstones = 1.5m

44. **What symbol was in the side tunnel?** *

45. **What is the angular position of the well? (Stop5)** *

Measured based on N=0, E=90, S=180, W=270, Round to nearest 5

46. **How wide is the path towards the tunnel in m?** *

47. **How high is the opposite wall in m?** *

Part 3 - After Test

Part 3.1 - Overall perception

48. **Please draw the path we walked on this map** *

Mark position of angular device, Put ID of Sheet here,

49. **Where would you put the structure on the picture?** *

50. **Would you've been able to do these tests alone without getting lost?** *
Markieren Sie nur ein Oval.

	1	2	3	4	5	
No, no stop at all	( )	( )	( )	( )	( )	Yes, all stops

51. **Do you think 1st / 2nd Grade school children (6-8) would get lost in the whole fortress?** *

Markieren Sie nur ein Oval.

( ) Yes

( ) No

( ) Sonstiges:

Part 3.2 - Demographic data

52. **How often did you go on the fortress in the last 4 Years (since End of BUGA)?** *

---

53. **What's your Gender?** *
Markieren Sie nur ein Oval.

  ( ) Male

  ( ) Female

54. **How old are you in years?** *

---

55. **What is your Height in m?** *

---

56. **What are you studying?** *
State Subject and Level (eg. Bsc WI)

---

57. **ID for this Run(Input by Conductor)** *
YYYYMMDD-
NumberOfRunOnThisDay(TV|HMD)

Bereitgestellt von

Google Forms