Master's thesis

A Case-study of Contemporary Presence Theory inside a Commercial Virtual Reality Game

Johannes Schirm

732571

Reutlingen University

Faculty of Informatics

Human-Centered Computing

Submitted on the 8$^{\text{th}}$ of March 2019

First examination:	Prof. Dr. rer. nat. Gabriela Tullius
Second examination:	Prof. Dr.-Ing. Cristóbal Curio
Project partner at the 'Steel Minions' game studio:	Dr. Jacob Habgood

Abstract

A substantial body of literature is concerned with models of presence—the sensory illusion of being part of a virtual scene—but there is still no general agreement on how to measure it in an objective and reliable way. For the presented case-study, contemporary theory was reviewed and applied in order to measure presence in the context of a comparison between continuous locomotion and teleportation in virtual reality. Thirty-seven participants played through an existing virtual environment of commercial quality, in which they had to collect several hidden items. Real-time assessments of presence were repeatedly collected using a single-item questionnaire, and in order to analyse dependencies, a post-study presence questionnaire had to be completed after the experience. Furthermore, three special events were naturally embedded in the environment in order to evoke physical reactions and behavioural measures of presence were collected in the form of head and controller tracking data in response to these events.

The results suggest that there is no significant difference in presence between the two compared locomotion techniques. However, as a more objective way of measuring presence than questionnaires and a less intrusive way than most physiological measures, behavioural measures are currently considered an important field of presence research [SBW17]. This thesis also presents a novel approach to employing and analysing behavioural measures.

Kurzfassung

Ein großer Fundus an Literatur befasst sich mit Modellen von Präsenz—der Wahrnehmung, selbst Teil einer virtuellen Szene zu sein—doch es gibt noch keine allgemein anerkannten Methoden zur objektiven und verlässlichen Messung dieses Phänomens. Für die präsentierte Fallstudie wurden gegenwärtige Theorien im Rahmen eines Vergleichs zwischen kontinuierlicher Fortbewegung und Teleportation in virtueller Realität zur Messung von Präsenz angewandt. Siebenunddreißig Testpersonen erkundeten die Welt eines kommerziellen Spiels in virtueller Realität, in der sie einige versteckte Objekte zu finden hatten. Als Messinstrumente wurden ein Fragebogen nach und Echtzeitbewertungen während der Spielerfahrung eingesetzt. Zusätzlich wurden zur verhaltensorientierten Messung von Präsenz drei Spezialereignisse über den Spielablauf verteilt. Diese sollten Muster in Kopf- und Handbewegungen der Testpersonen provozieren, die ein Indikator für Präsenz sein können.

Die Ergebnisse weisen darauf hin, dass es hinsichtlich der gemessenen Präsenz zwischen den beiden verglichenen Fortbewegungsarten keinen signifikanten Unterschied gibt. Ungeachtet der Auswertung dieser speziellen Fallstudie stellen verhaltensorientierte Messmethoden einen wichtigen Bereich der Präsenzforschung dar, weil sie objektiver als Fragebögen und weniger intrusiv als die meisten physiologischen Methoden sind [SBW17]. Diese Arbeit stellt daher zusätzlich einen neuen Ansatz vor, verhaltensorientierte Messmethoden einzubinden und deren Ergebnisse zu analysieren.

Acknowledgements

Special thanks are due to Gabriela Tullius, who gave final feedback on the experimental design, actively supported the statistical evaluation of results and aided the publication of our conference paper. Equally special thanks are due to Jacob Habgood, who made the PSVR game 'The Chantry' available for modification, run the experiment with his students and also aided the publication of our conference paper. I would like to thank them both very much for their support with this exciting project!

With regards to this master's thesis, I want to thank Gabriela Tullius and Cristóbal Curio for undertaking the first and second examination. Last but not least, I want to thank David Moore and Andrew Hamilton from the 'Steel Minions' game studio at Sheffield Hallam University for their frequent support in the challenging environment of PlayStation development.

Contents

1 Introduction

Typical virtual reality setups do not allow users to explore virtual environments larger than the physical tracking space. Research into redirected walking [RKW01] and specialised treadmills [SSU95] have provided various solutions to this problem, but these often require larger than average tracking spaces or expensive additional hardware. Without a clear solution, many published virtual reality games choose to avoid locomotion completely or implement locomotion systems which evoke motion sickness or are unintuitive for many users [HWMA17]. However, when working with fixed virtual reality setups and smaller tracking areas, ease of locomotion is probably the most critical aspect of the user's interaction experience.

After comparing three commonly used locomotion techniques, Habgood et al. suggested that node-based locomotion combines the advantages of free locomotion (intuitive, but evokes motion sickness) and avatar-based teleportation (much less motion sickness, but also less intuitive) [HMWA18, p. 375]. With this system, users can only move through the virtual environment on a predefined node-graph. Adjacent nodes are represented by a footstep icon in world-space. Users have to look at these nodes and press a button on their controller to start the transition. A surprising finding in this context was that '[...] rapid movement [between nodes] in very short bursts (<300 ms) doesn't produce any greater feelings of motion sickness than teleportation' [HMWA18, p. 377]. However, rapid motions are often categorically avoided in the design process of virtual reality applications, which leads to the majority of locomotion systems being based upon teleportation [HWMA17].

The aim of the presented case-study is to determine whether continuous locomotion makes users feel more present in their virtual environment, as compared to being teleported from spot to spot. These two conditions will be referred to as $\mathrm{L_C}$ for locomotion with rapid movements between nodes (continuous locomotion) and $\mathrm{L_T}$ for locomotion with direct teleportation to nodes. The hypothesis for this case-study is that users of $\mathrm{L_C}$ are significantly more present in a virtual environment than users of $\mathrm{L_T}$. This is a logical expectation, since a more continuous navigation experience might be able to more effectively support the illusion of presence.

An existing virtual environment of commercial quality will be used to provide participants with an engaging task and several measures of presence will be taken during and after the experience. Recorded levels of presence and additional meta data will be compared between $\mathrm{L_C}$ and $\mathrm{L_T}$ in order to determine whether the previously stated hypothesis holds.

Presence was also chosen as the main independent variable not only because it is considered one of the most important general factors in user experience in virtual reality, but also because its measurement and models are currently subject to intensive research. This thesis documents the process of designing the experiment and analysing its results—not only to compare L_C and L_T, but also to provide insights relevant to the field of presence research.

1.1 Objectives

The foremost challenge in realising the proposed case-study and coming to a reasonable conclusion is the design of an experiment which provides an appropriate context for measuring presence. The experimental design presented in this thesis will not only include details about the selected measures of presence and organisational information, but also general guidelines for the virtual environment. Although the virtual environment used for this case-study is already of commercial quality, there will be special requirements for the main task and the experimental real-world setting.

In order to design an experiment which measures presence according to the state of the art, available literature has first to be reviewed in-depth. Many models have been proposed that try to decompose presence into independent factors, and it is not an easy task to decide which one to use. Therefore, an overview of the most relevant literature shall be provided, discussing different approaches in the context of the proposed case-study.

After appropriate measures of presence have been decided on, they need to be integrated correctly into the virtual environment used for the experiment. A commercially published virtual reality game has already been expanded by some of the most important features needed for experiments on human-computer interaction in environmental narrative games. Using these new interfaces, an engaging task shall be implemented in the existing environment which provides ideal conditions for participants to be present.

The experiment shall be run with at least 30 participants. In the resulting dataset, presence values shall be compared between L_C and L_T for each measure individually, validating or invalidating the initial hypothesis that users of L_C feel more present than users of L_T. In addition, the results of all measures shall be compared amongst themselves and to meta data about each user's background and interaction behaviour. This evaluation is expected to provide insights which could be relevant to future research on presence.

1.2 Structure

Following a top-down approach, this thesis is structured in a way that specifics of the implementation are introduced as late as possible. For example, the experimental design will be kept as generalisable as possible, without limiting it to the actual implementation environment. It is only in the implementation section that details about the implementation are covered.

After a compact summary of contemporary presence theory in section 2, the experimental design for the proposed case-study is explained in detail in section 3. It addresses the proposed instruments (section 3.1), necessary additional data (section 3.2), general precepts of this case-study (section 3.3) and details about the procedure and ethics (section 3.4 and section 3.5).

In section 4, relevant decisions made when implementing the experiment for this case-study are discussed, for example in section 4.1 and section 4.2 with regards to the virtual environment. Then, the different phases of the experiment are documented in section 4.3, section 4.4 and section 4.5.

The results of this case-study are presented in section 5 and discussed in section 6. Potential questions for further research are stated in section 7. The appendices provide supplemental material on the experiment.

2 State of the Art

Obtaining reliable measurements of presence is not easy. Existing methods either rely on subjective assessments of participants or on specifics of the virtual environment they are applied in. In a recent literature survey, Skarbez, Brooks and Whitton summarised the history of presence research and recommended 'the use [of] multiple measures of different types whenever feasible. If all the measures suggest the same interpretation, then the results can be used with greater confidence' [SBW17, p. 96:32].

Three main categories of presence measures are discussed and used within literature: (1) Subjective, (2) physiological and (3) behavioural measures. Slater et al. have presented a psychophysical evaluation of the main factors contributing to presence for specific setups, but it is important to note that this work does not provide psychophysical measures of presence itself [SSC10, p. 92:8]. All other approaches can be assigned to one of the three mentioned categories. In this section, each of them is reviewed in more detail.

2.1 Subjective

The general challenge with subjective measures lies in the concept of presence used to design questions and in particular the way these are understood by participants. For example, Slater compared this to asking a person as how ‘colourful’ they perceived yesterday [Sla04, SG07]. Still, there are many questionnaires available that have been shown to be ‘valid, sensitive, and reliable’ [SBW17, p. 96:28]. Table 3 in the literature survey by Skarbez et al. [SBW17, p. 96:26] gives a more complete overview of these.

Most of them are post-study questionnaires, summarising the participant’s whole experience in the virtual environment. Those by Slater, Usoh and Steed [SUS94] and Witmer and Singer [WS98] are most commonly used, as well as the Igroup Presence Questionnaire [SFR01]. Bouchard et al. propose a 1-item instrument [BRSJ+04], which is reported to be working reliably in spite of its simplicity: ‘Results show that the question is well-understood, reliable between tests for the same users, correlates better with the Witmer-Singer PQ than either the Perceived Realism Scale or the Witmer-Singer ITQ, and is sensitive between high and low levels of presence’ [BRSJ+04, p. 96:27]. An important advantage of this instrument is the possibility for participants to give assessments in real-time.

2.2 Physiological

Even though physiological measures are most objective and provide real-time data, they often require special equipment attached to the participant, which could potentially influence presence through distraction [SBW17, p. 96:31]. They are most frequently used in studies featuring virtual environments that ‘are known to affect physiological signals in certain ways’ [SBW17, p. 96:31], for example threatening or stressful situations.

Meehan et al. [MIWP02, p. 650] were able to show that the difference in heart rate—the most distinct objective measure in their opinion—correlated to the well-known presence questionnaire by Slater, Usoh and Steed. Hoffman et al. examined the practicability of utilising functional magnetic resonance imaging for measuring presence and surprisingly noted that participants ‘reported experiencing a strong illusion of presence’ [HRC+03] in spite of the distracting environment. Deniaud et al. used several physiological measures for analysing a driving simulation and concluded that ‘presence measurement can’t be only based on subjective measures’ [DHJM15].

2.3 Behavioural

Skarbez et al. argue that ‘behavioral measures represent a promising area of study that has so far been understudied’ [SBW17, p. 96:32] and point out that these can—unlike physiological measures—almost always be integrated naturally into virtual environments, without disturbing the participant or making the experimental design too complex. Essentially, measures of this type try to evoke specific reactions in participants which are then either manually categorised or statistically evaluated.

Early ideas for this type of measure by Sheridan focused on natural reactions to specific cues, for example continuing to follow social conventions, even when experiencing a non-shared virtual environment, and dodging an object on a collision course [She92, p. 4]. Nichols, Haldane and Wilson categorised observed reactions on startle events into physical, verbal and no reaction and found this to significantly correlate to the feeling of having ‘visited’ the virtual environment [NHW00, p. 478].

Similar to physiological measures, behavioural measures are often criticised for their strong reliance on the specific virtual environment they are used in. However, some types of behavioural measures do not rely on a specific virtual environment, for example the ‘comeback rate’ used by Thie and van Wijk, where it was determined whether participants would voluntarily come back into the virtual environment after the actual experiment [TW98].

2.4 Summary

In section 3.1, there will be a more detailed discussion on which instruments would be most appropriate for the proposed case-study. Summarising the state of the art, there are plenty of ways in which any measure of presence could be designed. Following Skarbez et al. [SBW17, p. 96:32], it seems to be beneficial for several measures of presence to be combined, depending on the specifics of the virtual environment the experiment is designed for.

Subjective measures are easy to integrate and analyse, while physiological and behavioural measures may be difficult to interpret. However, subjective measures alone are not expected to lead to sufficiently comprehensive results, as they are just based on the participant’s perception. Behavioural measures are usually designed to be transparent to the user and are therefore a promising alternative to physiological measures. For some contexts, it might therefore make sense to combine subjective and behavioural measures.

3 Experimental Design

It would make sense for the proposed case-study to integrate the intuitive, node-based locomotion system presented by Habgood et al. [HMWA18], which is minimally distracting in its interaction mechanics (and its visual representation) and therefore especially well-fitted for an experiment in which presence is measured. But knowing what a sophisticated concept presence is, there are many more factors that need to be taken into account. This section aims to define and discuss all requirements that the experimental procedure of the proposed case-study would need to fulfil.

3.1 Instruments

Following the recommendations from section 2, where current literature was reviewed, three different measures of presence were selected for this case-study: (1) A *subjective* post-study questionnaire, (2) a *subjective* real-time instrument and (3) a *behavioural* measure in which startle reflexes are evoked and analysed afterwards, both visually (by hand) and statistically.

The reason why these specific instruments were chosen is that subjective real-time measurements could add more value to the results of the post-study questionnaire which is part of almost every presence study. As an objective measure, the analysis of startle reflexes could not only give the most reliable results, but also lead to new approaches to behavioural measures independently from the outcome of the case-study.

3.1.1 Post-study

Post-study questionnaires are commonly used to measure presence in a range of research contexts, but the Presence Questionnaire (PQ) by Witmer and Singer [WS98] is reported to work particularly well together with the real-time instrument described in section 3.1.2. The Immersive Tendencies Questionnaire (ITQ) by the same authors supplements the PQ with questions about personal conditions that could influence presence. Revised versions of the PQ (3.0) [UQO04b] and the ITQ (3.01) [UQO04a] from 2004 are used for this case-study. All questions of both PQ and ITQ have to be answered on a 7-point scale, one at a time without correcting previous answers.

3.1.2 Real-time

A post-study questionnaire cannot assess presence in real-time, which is why the 1-item instrument presented by Bouchard et al. [BRSJ+04] is considered for this case-study. A prerecorded voice should ask participants the following question at predefined points throughout the session: ‘On a scale from zero to ten, to which extent do you feel present in the scene?’

It is criticised by many that repeatedly asking participants to assess their presence in real-time ‘intrudes on the very presence illusion one is trying to measure’ [MIWP02], but the referenced real-time instrument was described as being minimally intrusive in comparison to its alternatives. Care should be taken to integrate the question naturally into the game progression, for example by having it asked by the narrator who is being presented as ‘part of the virtual environment’ anyway. This measure should not be overused.

3.1.3 Special Events

Behavioural measures of presence are less common in the literature, and so they are used much more rarely (see section 2.3). Similar to physiological measures, they require dedicated cues (which are expected to evoke certain behaviour) to be integrated into the virtual environment. Within this thesis, these cues will be referred to as ‘special events’. Physiological and behavioural measures are similar instruments, as they both rely on special events and can be difficult to interpret. But since physiological measures require specialised hardware attached to participants, this case-study focuses on behavioural measures as a non-intrusive means of measuring presence.

This creates the need to prepare the virtual environment appropriately by integrating a number of different special events. Because none of the well-known publications discuss general event types, three categories of special events were thought of for this case-study, each of which represents a slightly different manner of evoking some sort of startle reflex in hand or head movements, with the main difference being the expected reaction profile:

- *Passive threat*
  Ideally in the midst of examining an item, a passive threat should be presented to participants. They would be likely to maximally focus on their interaction with the virtual environment in this situation. The threat should be something inherently intimidating to most people. Present participants would be expected to react with their hands.

- *Social presence*
  At an unexpected moment in the game progression, participants should face a human model (social presence) in their private space. According to Sorokowska, a distance between 60 cm and 80 cm is likely to be just within the private space of any participant [SSH+17]. However, care should be taken to not move the model too close to participants, so they can recognise it as a whole quickly enough. The model itself should not be too realistic, as it would be likely to fall into the 'Uncanney Valley' [MMK12] otherwise. This event would be expected to evoke a startle reflex affecting head and hand movements.

- *Active threat*
  Induced by an interaction with the virtual environment, participants should be approached by an object on a collision course, similar to Sheridans early idea of a ball flying towards the user [She92, p. 4]. Being focussed on their interaction, participants should have enough time to dodge this active threat, but not enough time to realise that there is no rational need to do so. Present participants would be expected to move their head out of the way of the object.

For the proposed case-study, it would make sense to implement one instance of each category as part of the main task. The tracking of head and hand movements does not require additional hardware in the context the proposed case-study: Throughout the whole experiment, participants will be wearing a head-mounted display and holding a controller in their hands, both of which provide absolute tracking data. The strength of reactions could be drawn from the resulting trajectory in three-dimensional space.

At least one additional 'baseline event' should be integrated somewhere earlier into the game progression. It should not be expected to trigger any specific behaviour and thus provide an interaction profile for each participant. This could help explain potential individual variance in the way participants engage with the virtual environment.

3.2 Additional Data

Since presence depends on a variety of factors, there are several additional questions which all participants would need to answer. For example, specific disabilities and different backgrounds in terms of video game and virtual reality exposure could have a significant effect on presence.

3.2.1 General

This group concerns data about the participant which could generally affect their experience of the experiment.

- *Age, gender and nationality*
- *Experience with video games on a 7-point scale*
- *Experience with virtual reality on a 7-point scale*
- *Disabilities in hearing and sight, including corrected vision*
- *Learning or attention disabilities*

It should also be documented which type of headphones each participant used, as their level of isolation can have an effect on presence.

3.2.2 Locomotion

This group concerns recorded data that is related to the locomotion system, which could be useful for detecting any anomalies in task performance.

- *Total elapsed time since the experiment started*
- *Whether the participant used L_C or L_T*
- *Name and distance of reached locomotion nodes*
- *Continuous indicators of engagement with the virtual environment*
  A sequence of named 'markers' should be recorded throughout the game, allowing for a more precise analysis of the specific experience of each participant individually. Accumulated position and rotation offsets should be recorded alongside new markers. This could give general hints on how actively participants explored the environment—whether they always looked around or did not move their head very much.

3.2.3 Gameplay

This last group validates the efforts made to keep the experiment scenario as natural as possible. The following general question could provide some information about each participant's subjective experience:

- *How much the participant liked their experience on an 11-point scale*

3.3 Precepts

It is difficult to predict how strong presence will be influenced by the rather subtle difference between L_C and L_T. The general precept in the design phase of this experiment is therefore to reinforce all factors which naturally lead to more presence in the virtual environment.

3.3.1 Adaptation

Many people have no or very little experience with virtual reality, which can affect their precision when it comes to more nuanced concepts like presence. Furthermore, it occurs quite frequently that participants without gaming experience are not able to build a mental model of the controller they are handed quickly enough, which creates the need to talk to the experimenter during the experiment. This would interrupt the participant's presence in the virtual environment, thus it should be completely avoided by design. Small interaction tests should be integrated in the form of an adaptation phase to objectively verify that all participants start the main part of the experiment with the same knowledge of all relevant key concepts.

In the case of this experiment, there are three main concepts that need to be communicated to participants before the main task starts:

1. **Controller**
   As participants will not see their hands and the controller in virtual reality, it is important to give them time to adapt to its layout before the actual task starts. This includes an explanation of the controller in reality and enough time to get used to it in virtual reality.

2. **Environment**
   Especially if participants are not used to gaming or virtual reality, it might be hard for them to understand what they can do and what they cannot. Therefore, the experiment application will introduce them to the general concept of virtual reality at the beginning.

3. **Locomotion**
   Participants being able to effortlessly use the node-based locomotion system is crucial for this experiment, as it could have a negative impact on their presence if they were always concerned with understanding how to use the system to accomplish more high-level tasks.

3.3.2 Commitment

Like attention, presence is likely to be dependent on intrinsic motivation to some degree. It is therefore considered important to give participants more motivation than just getting a number of repetitive tasks done.

Whenever humans experience 'flow' in the sense of sustained attention, it is because they manage to keep up with a natural flow of events that they can engage with. Of course, an experiment still requires a certain amount of repeated measures to yield statistically meaningful data, but a detailed virtual environment and a fun story would be expected to naturally engage participants. Whenever possible, the task in this experiment should feel more like a game than an experimental procedure.

3.3.3 Naturalness

Similar to commitment, for which participants are intrinsically motivated to accomplish tasks in the experiment, naturalness will make it more likely for them to behave in a consistent way and produce less unpredictable noise. Optimally, participants just get a short introduction into how to use the equipment and then play a fun game in which they behave as naturally and non-self-consciously as possible, while producing all the data needed.

The general precept is therefore to inform participants about everything they need to know right at the start, but then avoid any direct instructions while they play the experiment to make their actions seem more natural.

- Special events (behavioural measures of presence) need to be naturally integrated into a short storyline that links all the experiment tasks and has the capability to direct attention naturally.
- A prerecorded 'instructor' should introduce themselves appropriately and gently guide participants through the whole experiment.
- Participants should not feel constrained by the experiment logic. At least during the main task, they should be able to complete all of its sub-tasks in any order they would like.
- To make the virtual environment feel more natural, audio effects and atmospheres should sound as realistic as possible.

3.3.4 Isolation

Isolation is often associated with negative feelings, but since 'flow' is the enjoyable experience of fully focussing on an activity, any distractions should be removed to enhance presence. Participants should therefore wear in-ear headphones and be advised to play through the experiment in one go, without any breaks in between. Of course, participants can still abort the experiment at any point in time, for example when experiencing motion sickness.

Apart from preparatory tasks which include showing relevant hardware to the participant, having them sign the informed consent and getting them comfortable with the virtual reality headset, all further explanation should be provided inside the virtual environment by the prerecorded instructor.

3.4 Procedure

The experiment will be run with at least 30 participants who will be randomly assigned to either $\mathrm{L_C}$ or $\mathrm{L_C}$. Apart from the difference in how transitions between locomotion nodes are performed, all other aspects of the procedure and the environment have to be exactly the same for both groups.

The general conditions for this experiment will be the same as for a similar experiment by Habgood et al. [HMWA18, pp. 374]. It utilised a teaching lab with specially prepared PlayStation VR development kits, where 3-6 participants could take part in the experiment in parallel. Habgood et al. did not find any significant differences between gaming and virtual reality 'experts' and 'novices' in their study. For this reason, but also to have a homogeneous group of participants that can be invited more easily, the experiment will be run with students from media and computer science courses.

Participants will be sitting on a chair for the duration of the experiment. They will be wearing the PSVR head-mounted display and holding a Dual Shock 4 controller in both hands. The principal researcher will help them if they need support with the equipment. The prerecorded instructor should slowly guide them through the whole game. Experiment-related instructions should be given in a virtual preparation room and in appropriate situations during the adaptation. Participants should be reminded to answer the post-study questionnaire (see section 3.1.1) directly after the experience.

3.5 Ethics

This experiment will be run in the context of 'REVEAL', a research and development project which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 732599. The project's ethics guidelines were followed when designing this experiment. Principal researcher is Dr Jacob Habgood from the department of computing at Sheffield Hallam University.

4 Implementation

This case-study has been designed to integrate the locomotion system of the 'REVEAL' framework [HMWA18, pp. 372–373], made for Environmental Narrative games [SW10, p. 34]. After one year of development, it was expanded by general interfaces needed for HCI experiments, such as dynamic data recording, game logic alternation for different groups of participants, audio recording and a virtual preparation environment [Sch18]. With the help of these interfaces and an existing high-quality virtual environment, an experiment application was implemented that satisfies all the requirements stated in section 3. This section document the implementation process.

4.1 Virtual Environment

Environmental Narrative games typically provide a continuous and natural experience with a strong focus on presenting an immersive environment, which makes them ideal for measuring presence. They often contain no animated avatars, and players are simply provided with a rich environment within which they have to accomplish engaging tasks.

'The Chantry' is an educational Environmental Narrative game developed for PlayStation VR by the 'Steel Minions' game studio [Min18] using the REVEAL framework. The game features an elaborate reconstruction of a historical Georgian house and a graveyard with realistic fog effects. Figure 1 shows four locations inside the house. The virtual environment for this case-study is a derivative of 'The Chantry'. Keeping the original game's detailed environment, its story was replaced by an experimental procedure which involves locating seven hidden items inside the house. The graveyard is used for a short adaptation phase at the start of the procedure.

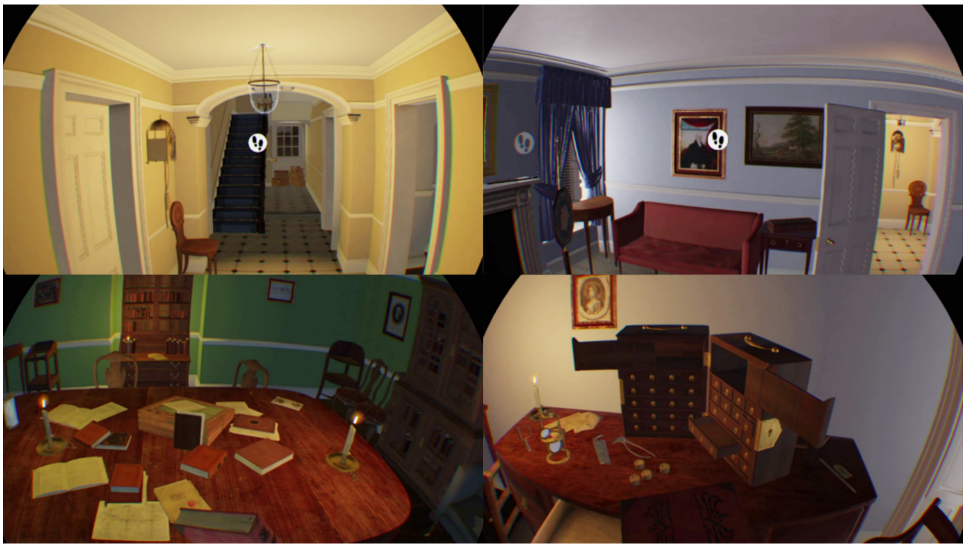


Figure 1: Four rooms from the commercial game 'The Chantry' [Min18], which provided the foundation for the case-study presented in this thesis. It features a detailed reconstruction of a historical house in Georgian style.

Real-time measurements (see section 3.1.2) are automatically taken by the experiment application. As soon as the question is started to be read out, an audio recording of 15 seconds in length is taken from the head-mounted display's internal microphone. The assessment has to be spoken out loud.

Appendix A contains floor plans for the ground floor and the first floor of the house. Some rooms of the historical house had not been reconstructed for the original game and are greyed out. Also, the plans only show doors which participants are able to interact with. The house is entered through the front door indicated at the very top of the ground floor plan.

Figure 2 shows the experiment application in edit mode, where the spatial graph of the REVEAL framework can be visualised and modified. Yellow boxes represent a locomotion node which users are able to navigate to if it is 'connected' to their current node. Blue logic nodes can be used to enable or disable individual connections (yellow lines) in the graph, and red trigger nodes can modify the spacial graph and execute REVEAL commands.

The locomotion graph was completely reworked to allow instant access to all parts of the house, making it possible to collect the seven hidden items in any order. As required in section 3.3.3, this makes the main task more natural. All locomotion nodes were given human-readable names (listed in Appendix B) to aid any posterior analyses of individual traces.

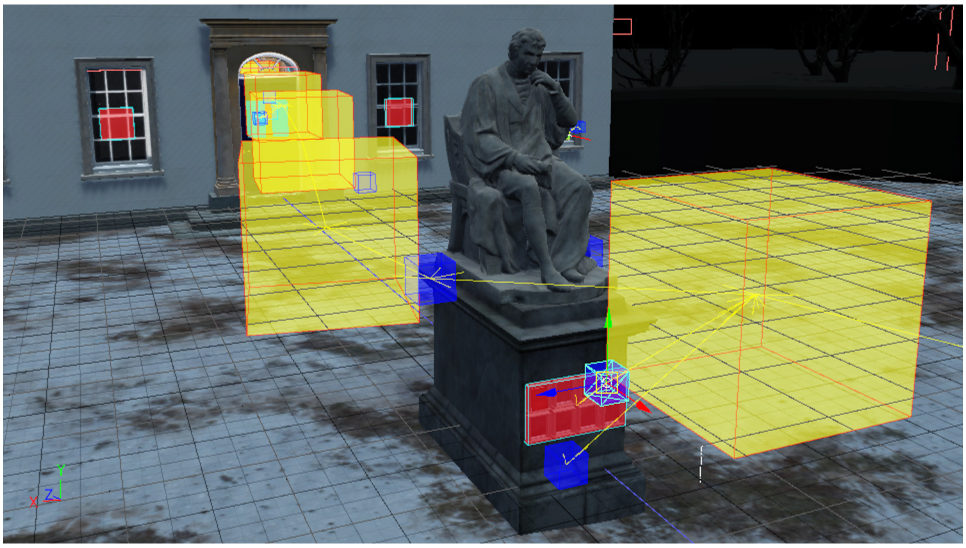


Figure 2: A screen capture of the 'PhyreEngine' level editor with REVEAL extensions. It was used to design the virtual environment for this case-study. Yellow, red and blue boxes represent locomotion, trigger and logic nodes.

The game logic for the adaptation phase is much more linear: Participants are briefed about the experiment in a virtual preparation room, complete two small tasks on the graveyard and then naturally arrive at the house. They are guided by a prerecorded instructor who introduces them to the virtual environment and gives comments on their progress. A complete script of the game progression can be viewed in Appendix C. The leftmost column contains 'markers' in bold print, which are necessary to record the order in which different parts of the game progression were experienced.

The original game employed L_C as its only locomotion technique. Thus, a teleportation-based variant (L_T) with a short fade-out and fade-in (<500 ms respectively) and no rapid, continuous movement between locomotion nodes was implemented for this case-study. The appropriate locomotion technique for each participant is selected automatically depending on whether their participant number (entered at the beginning) is even or odd.

Stylised audio atmospheres with 'ghostly' sounds that no visual cue was presented for were removed and replaced with ambient audio atmospheres. Locomotion nodes were placed about 1.63 m above the floor, which is average eye height in the United Kingdom. But since participants will be sitting on a chair, virtual eye height offsets of a few centimetres are not expected to have a significant impact on their perception of the virtual environment.

4.2 Special Events

In section 3.1.3, three categories of special events were defined, all of which aim to evoke some sort of startle reflex in participants. With the help of the REVEAL framework and several new assets, three special events (one of each category) were integrated into the virtual environment of this case-study. All of them have to be encountered in order to complete the main task. For more information on the context, see Appendix C from page C6 onwards. During each event, the transformation matrices of the head-mounted display and the controller are recorded with 25 samples per second in tracking-space.

No standardised procedure could be determined that would be specifically capable of analysing the resulting trajectory, as the ideal approach would greatly depend on the specific event. But as a first step—to compare the comprehensiveness of these measures and to provide supplementary insights into the correlation between L_C and L_T—this case-study aims for a visual analysis of recorded tracking data appropriate to each event.

All three special events are well within the requirements of a 12+ PEGI age rating for games (the same age rating as the commercial version of the game), and all participants of the study will be older than 18 years. The events are capable of provoking an initial startle response in players, but are not scary after the initial reaction.

4.2.1 Baseline

Two additional, non-startling events were integrated into the adaptation phase (more detail on the adaptation in section 4.4), providing a baseline for each participant's general engagement with the virtual environment:

- **Key**
  To unlock a door on the graveyard, participants have to find and pick up a nearby key (see Figure 8b). Aligned with the real-world controller, the key can be examined for 9 seconds. This event was expected to record participants naturally interacting with the key in their hands.
- **Door**
  When eventually unlocking the door, participants see a ghost behind it (see Figure 8c). This event is expected to record participants while they naturally interact with their environment, for example curiously adjusting their head position to get a better view through the door.

4.2.2 Passive Threat

In one room, participants pick up one of the seven missing books from a table. The book is oriented during the pick-up animation so that its back-cover faces upwards, revealing an exceptionally large spider on it. Due to common arachnophobic tendencies, participants are expected to primarily react with their hands. The spider does not move.

Figure 3 shows the prepared book in the level editor. Later in this thesis, this event will be called the '**spider** special event'. The location of this encounter is marked with a spider symbol on page A1 of Appendix A.

Figure 3: This static model of a spider is attached to the back of one of the items that participants have to collect during the main task.

4.2.3 Social Presence

When reaching the end of a narrow hallway, participants are not able to enter the only accessible room within their reach because its door is locked. A few seconds after their arrival, while they try to open the door, a ghost appears behind them. When they turn around to continue their exploration, they unpreparedly face it with just 70 cm of distance.

Figure 4 shows the ghost next to the locomotion node in the level editor. This event will be called the '**ghost** special event'. The location of this encounter is marked with a ghost symbol on page A1 of Appendix A.

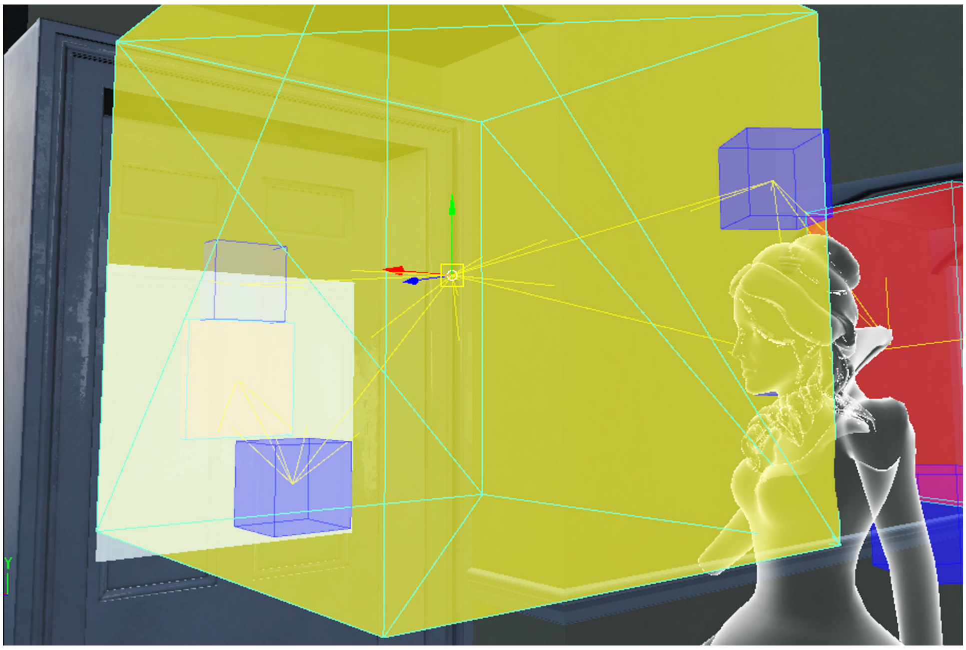


Figure 4: The ghost appears next to the locomotion node and is only about 70 cm away from the node's centre where participants will be located.

According to Sorokowska, this is likely to be within the private space of any participant [SSH+17]. A ghost was selected because it creates social presence without falling into the Uncanney Valley, which a more realistic human model would [MMK12]. This '**ghost** special event' was expected to evoke a strong startle reflex affecting head and hand movements.

In fact, Figure 5 shows the head movements of two volunteers reacting to the **ghost** special event during a pilot experiment. Both of them come from a technical background and were substantially involved in the development of the original game, yet their reaction was astonishing: They both featured a strong startle reflex, discernible by a sudden acceleration (at 4 and 6 seconds respectively) and a temporary offset of almost 20 centimetres.

The **spider** and **chandelier** special events did not cause reactions of this strength. However, it is important to note that both volunteers played the pilot experiment in the evening with nobody else in the room. The parallel setting of this case-study and the otherwise immense organisational overhead do not allow this situation to be recreated for all participants, but similar reactions would still be expected in the situation described in section 3.4.

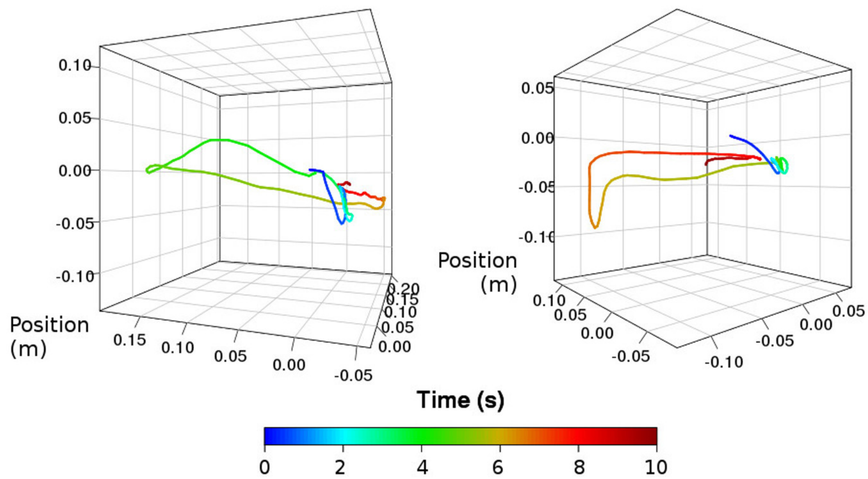


Figure 5: Two participants volunteered for a pilot experiment just with behavioural measures. This figure visualises their reaction (head movement) on the **ghost** special event. The colour-scale represents the elapsed time in seconds since the participants arrived in front of the locked door.

4.2.4 Active Threat

In order to find another missing book, participants will have to pull at a rope which is connected to a metal construction which in turn secures a chandelier at the roof of the staircase. The rope snaps and falls downstairs. The moment after, emergent cracking sounds direct attention back to the chandelier, which then quickly (within 1.5 s) swings towards the participant. Present participants are expected to instinctively move their head out of the way of the chandelier to avoid the imminent 'collision'.

Figure 6 shows this mechanism and the chandelier in the level editor. This event will be called the '**chandelier** special event'. The location of this encounter is marked with a chandelier on page A2 of Appendix A.

Although this event poses an active threat, its general pace is less flexible between different playing speeds. While very experienced participants could predict what is going to happen just from the emergent cracking sounds, less experienced participants could be focussed on something else and notice the threat too late. Timings were chosen with this limitation in mind.

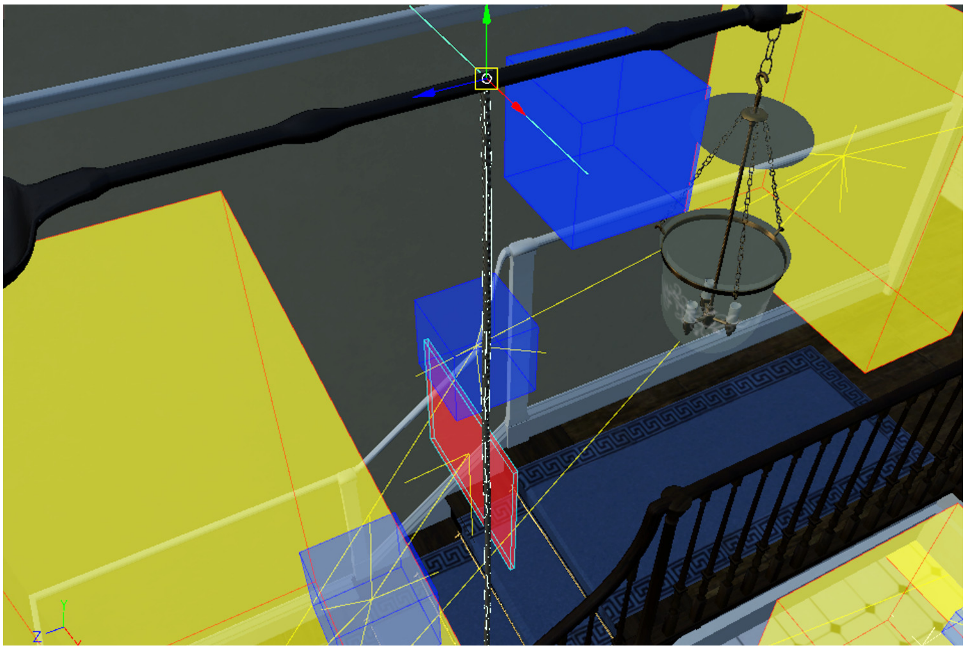


Figure 6: Once the rope (in the middle) has been pulled, the complete metal construction swings down to the left where participants will be standing.

4.3 Preparation Phase

Before participants immerse themselves in the detailed environment of the game, they are shortly briefed in a preparation room (see Figure 7) which is completely separate from the rest of the virtual environment.

As required in section 3.3.1, a short interaction test is performed at the beginning, where specific buttons on the controller have to be pressed in order to continue. Participants are then explained the concept of presence and prepared for giving spoken assessments of their presence throughout the game (see section 3.1.2) by the instructor. The exact script for this procedure can be viewed on page C1–C2 in Appendix C.

The first real-time measurement is taken directly after the introduction. Due to the minimal nature of the preparation room, it could later be used as the baseline for all following real-time assessments.

Once the preparation phase is completed, a slow fade-out and fade-in brings participants to the graveyard.

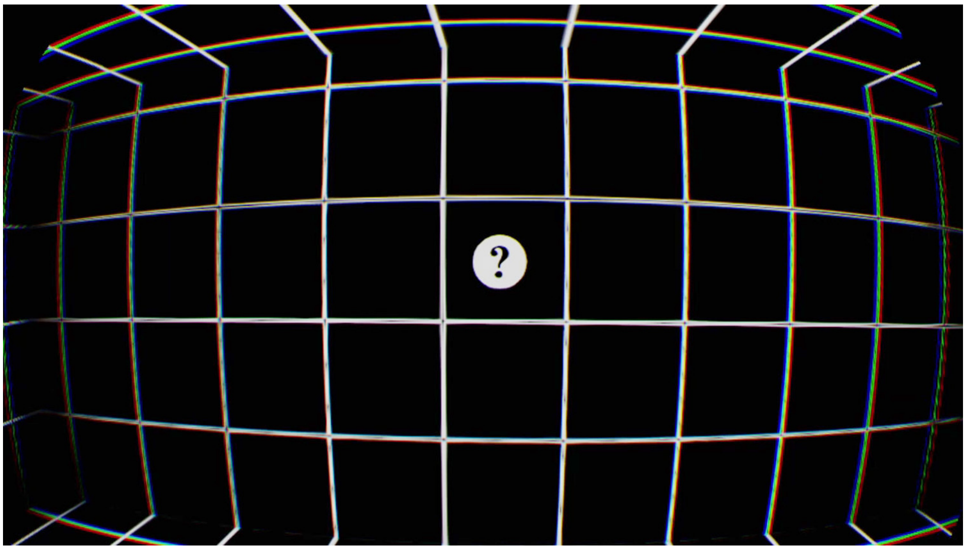


Figure 7: After they entered the number they were assigned, all participants find themselves in a simplistic and rather neutral preparation room.

4.4 Adaptation Phase

To leave participants time to adapt themselves to the general feeling of being in virtual reality and to get an intuitive feeling for how to use the locomotion system, there is an adaptation phase before the main task. This is also justified by the short storyline described in Appendix C.

Figure 8 shows four moments of the adaptation phase. After the preparation phase, participants are introduced to the locomotion system (a), find a key and examine it 'with their own hands' by moving the controller around (b), use this key to unlock a door (c) and eventually follow the ghost to the main task (d). This phase is expected to take around two minutes at an average playing speed. By the time participants leave the graveyard, they should be able to naturally interact with the game and focus on the main task.

This satisfies the precept of adaptation (see section 3.3.1), and simultaneously the precept of naturalness (see section 3.3.3) by avoiding direct instructions and embedding the process of learning about the game's mechanics in a natural sequence of actions. Additionally, the adaptation phase provides a baseline for general engagement with the virtual environment. Two behavioural measurements are taken (while examining the key and after opening the door) that could help with creating a general profile of their interaction behaviour and providing more context for later measures.

Figure 8: The adaptation phase takes place outside the house used for the main task. After 'waking up' at the graveyard (a), participants find a key at one of the monuments (b), open a barn containing a ghost (c) which shows them the way to the house (d) where the main task begins.

4.5 Task Phase

Coming from the graveyard, participants find themselves in the front garden of the historical Georgian country home (see Figure 9). Before entering the house, they have to examine a nearby statue, which provides the motivation for the main task: As shown in Figure 10a, there are eight stone frames, but only one has a red book in it. Alongside an appropriate remark by the instructor, this is expected to clearly communicate the goal of finding the seven missing books in the house.

This satisfies the precept of commitment (see section 3.3.2) and naturalness (see section 3.3.3), as participants would be expected to be curious and wanting to find out more about the missing books by exploring the mysterious house in front of them. Also, as mentioned in section 4.1, participants can freely choose the order in which to collect the books. Their positions are marked in red on the floor plan in Appendix A.

Figure 9: This is the house in which the main task has to be accomplished. A statue in the front garden motivates the task.

Figure 10: While searching the house for the missing books, participants will trigger several special events. A spider on a book in their hands, a ghost in their personal space and a chandelier swinging towards their head—plenty of reasons to feature specific behaviour for present participants.

General game design principles were applied when implementing this task in order to make a flow experience more likely. The instructor counts the number of collected books and keeps participants updated on how many remain. Three books were placed downstairs, four upstairs, and with the exception of two rooms, there was one book in each accessible room. All books look like the first book at the statue and are either hidden in a drawer or lying on a table. Only one book (at the chandelier) lies on the floor.

On their way of searching the house, participants have to visit almost all accessible rooms and experience the special events described in section 4.2. These are the **spider** special event (see Figure 10b), the **ghost** special event (see Figure 10c) and the **chandelier** special event (see Figure 10d). Once participants were able to find all seven books, they are teleported to the statue again, which now has the missing books in their frames again. They are then thanked for their participation and reminded that there is a post-study questionnaire (see section 3.1.1) to complete.

5 Evaluation

This experiment was run—in accordance with section 3.4 and section 3.5—as part of the Horizon 2020 REVEAL project and under the same conditions as the locomotion study by Habgood et al. [HMWA18]. 37 students (5 female, 32 male) from technical courses at the faculty of Science, Technology and Arts at Sheffield Hallam University volunteered to take part. Aged between 19 and 24 years (M=21.54, SD=1.28), they rated their experience on a scale of 0 to 6 to be 5.46 (SD=0.8) with video games and 3.08 (SD=1.83) with virtual reality. They were randomly assigned to one of the two locomotion groups—19 used L_C and 18 used L_T. Appendix D contains more details on the specific data that was collected for each individual participant.

After signing an informed consent and answering some general questions (see section 3.2) through an electronic questionnaire application, participants were shown how to use the equipment. In order to minimise distraction, they were asked to use in-ear headphones if possible. 75.7 % brought their own in-ear headphones, the others were given over-ear headphones. With the headset donned, participants first had to select their participant number in the experiment application. The numbers were evenly distributed over the natural numbers starting from zero. For maximum data privacy, each participant was assigned their number through a sticky note on their informed consent, which they removed before handing the signed consent back.

Once participants entered their number in the modified main menu from the original game, they were teleported to the preparation room, where the preparation phase (see section 4.3) began. From there, the game progressed as described in Appendix C. On average, participants spent 3.48 minutes (SD=0.97) in the adaptation phase and 11.04 minutes (SD=3.51) in the task phase. After they reached the end of the experiment, they completed the post-study questionnaire (see section 3.1.1) through the same electronic questionnaire application used at the beginning of the experiment.

5.1 Data Preparation

All 37 participants successfully completed the post-study questionnaire. 35 of them completed the main task and were included in the analysis of tracking data and real-time assessments. The audio recordings with real-time assessments were transcribed into text files. For 28 out of 37 participants, a complete set of assessments is available. This was surprising, as the instructor clearly stated that assessments should be spoken out loud in response to the question mentioned in section 3.1.2, which participants had to confirm by pressing a button. It is possible that some participants felt inhibited speaking out loud in the lab environment.

Instead of triggering real-time measurements in set time intervals, they were assigned a fixed position in the game progression to increase comparability between participants and to better adapt to different playing speeds. Some participants collected the books in an order or speed that made two successive measurements overlap—skipping one of them due to the question already being asked. Since the temporal distance between overlapping measurements was 10.16 seconds (SD=4.35) for the 9 affected participants, the values for the earlier measurement were also used for the skipped measurement.

5.2 Subjective Measures

Both instruments that were used to measure presence subjectively (post-study and in real-time) have already been used in literature before. This analysis structures the results obtained during the experiment and discusses them within the context of this case-study.

5.2.1 Post-study

The PQ and ITQ post-study questionnaires by Witmer and Singer [WS98] (see section 3.1.1) were completed by participants after the experiment through an electronic questionnaire application. Showing one question at a time, a slider ranging from 0 to 6 with one label for each extreme was displayed. The results show no significant difference between the two locomotion groups both for the mean values of presence (t(34.835)=0.6915, p=0.49) and for immersion (t(34.754)=-0.743, p=0.46).

Examining the answer set for the questionnaires with respect to self-evaluation of performance (e.g. questions 15 and 16: *'How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?'*), participants reported that they adjusted to the virtual environment quickly (M=5.02; SD=0.98) and felt proficient (M=4.67; SD=1.151). This corroborates the presented view of the virtual environment in terms of professionalism. On question 13 (*'How involved were you in the virtual environment experience?'*), participants generally rated just above 'mildly involved'. There is a tendency of a higher difference to the L_T group (t=1.49; df=52.97; p=0.1397) than the L_C group (t=0.95; df=53.912; p=0.3415). This could be an interesting initial question for future research on locomotion in terms of involvement.

5.2.2 Real-time

Ten real-time assessments of presence (see section 3.1.2) were integrated into the game progression. Using the first value (which was measured in the rather neutral preparation room from section 4.3) as a baseline, Figure 11 shows all δPresence assessments grouped by marker and locomotion group. No obvious differences between L_C and L_T are visible, and the data seems to be highly dispersed between measurements.

The measurements were distributed as follows: 1 in the preparation room, 2 during the adaptation, 6 during the main task and 1 at the end, after participants had been teleported back to the statue in front of the house to see that all the books are now back in their frame. To keep the labels in Figure 11 more readable, markers are not represented by their full name. Table 1 shows the mapping from the IDs onto full marker names.

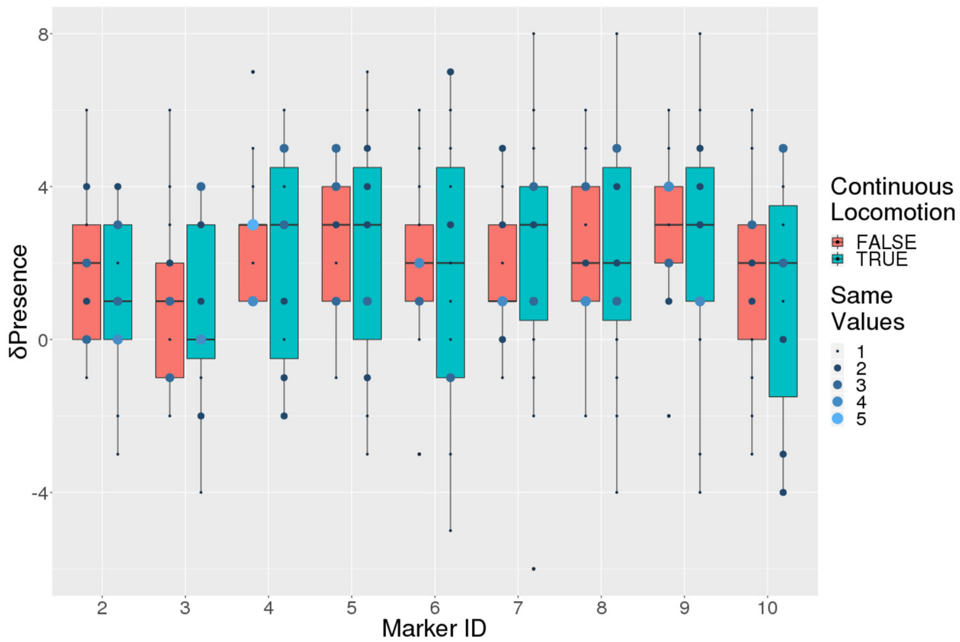


Figure 11: An overview of real-time presence for participants with a complete data set (n=28), separated by locomotion groups. δPresence is always zero for the baseline measurement, hence it is not shown here. Marker 2 and 3 belong to the adaptation phase, 4-9 to the main task and 10 to the ending.

Table 1: The mapping from marker IDs as shown in Figure 11 onto marker names as shown in the left column of the game script in Appendix C. The IDs were assigned to marker names in the most likely order of exploring the house. However, this does not necessarily represent the path taken by most participants, as they could freely choose their way through the house.

ID	Name	Phase
(1)	(**Preparation**)	Preparation
2	**Adaptation_Key_PickUp**	Adaptation
3	**Adaptation_Barn_Ghost**	Adaptation
4	**Task_DrawingRoom_Enter**	Task
5	**Task_DiningRoom_Spider**	Task
6	**Task_Ghost_Item**	Task
7	**Task_BestBedroom_Enter**	Task
8	**Task_CaptainsRoom_Leave**	Task
9	**Task_DrJennersRoom_Door**	Task
10	**End**	Task

The results of the post-study questionnaire and the real-time assessments are significantly correlated ($r(26)=0.66$, $p=0.0001$, 95% confidence interval). When analysing the correlation with respect to the locomotion groups, both are significant with 95% confidence interval: For the L_C group $r(13)=0.888$, $p<0.0001$ and less for the L_T group $r(11)=0.54$, $p=0.05$.

As mentioned in section 3.1.2, there are some doubts in the literature as to whether asking for presence assessments in real-time has a significant impact on the presence to be measured [MIWP02]. However, almost one third (28.6 %) of the participants of this case-study reported very high levels of presence (9 or 10) at least once, and 60 % reported high levels of presence (8, 9 or 10) at least once. While it cannot be denied that frequent real-time measures could have an impact on the overall experience, this indicates that the question itself was integrated into the virtual environment in way that would not significantly diminish presence in the moment it was asked.

5.3 Behavioural Measures

Three special events were designed (see section 4.2) to evoke specific behaviour in participants, so it could be non-intrusively recorded as head and hand tracking data. This analysis concentrates on head movement in the **chandelier** and **ghost** special events. With no standardised procedure to analyse these particular events in terms of presence, a visual analysis of appropriate spatial and temporal aspects of the tracking data was performed.

5.3.1 Active Threat

The **chandelier** special event, representative of the *active threat* category, was expected to make participants instinctively move their head aside to prevent a ‘collision’. This movement characteristic was (1) expected to be most meaningful when analysed over time and (2) not expected to result in significantly higher movement speeds. Hence, travelled distance (in all three dimensions) is used as the main metric for this event. Figure 12 visualises for each participant how far their head-mounted display travelled during the exact 1.5 seconds the chandelier swung towards them. For comparison to the subjective real-time measurements (see section 5.2.2), an indicator of ‘total reported presence’ was calculated for each participant. Represented as percentage, this is the normalised sum of all available assessments. This also makes the value independent from whether all assessments were given.

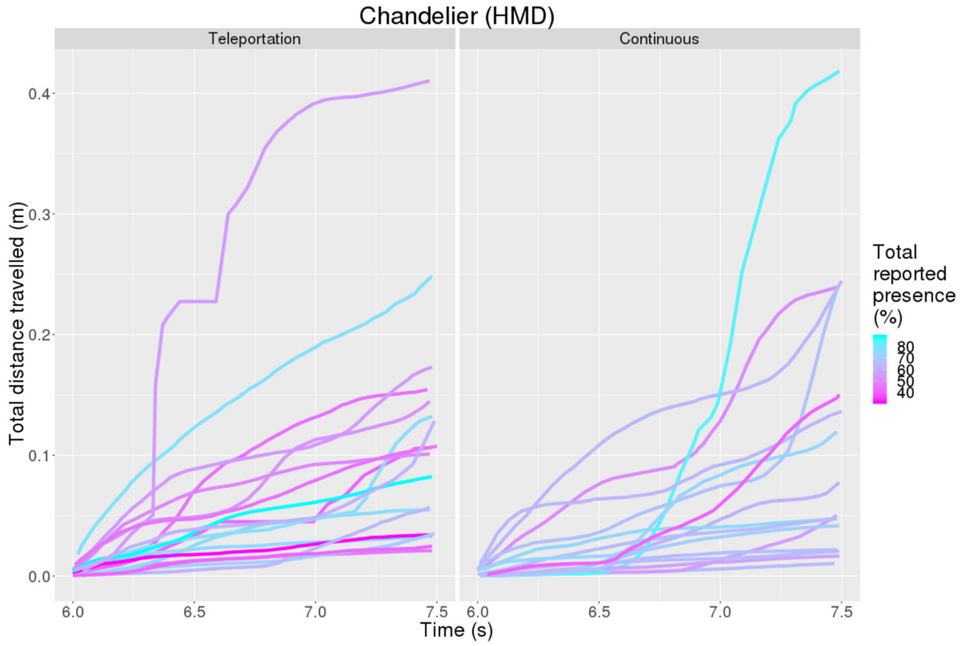


Figure 12: For each participant (n=35), faceted by locomotion group, this figure shows their accumulated head movement distance over time, recorded with samples of 25 frames per second during the **chandelier** special event. The time span shown is the exact moment in which the chandelier swung downwards. In addition, total real-time presence has been colour-coded.

5.3.2 Social Presence

The pilot experiment (see Figure 5) provides a well-founded starting point for the **ghost** special event, representative of the *social presence* category. This movement characteristic was expected to feature (1) a notable acceleration and (2) a directed trajectory with a length of roughly 20 centimetres. Hence, bounding box dimensions (the sum of all axes) and speeds are used as the main metric for this event. Figure 13 shows static bounding box dimensions for each participant, considering 7.5 seconds of tracking data for the event. The first 2.5 seconds were skipped, as participants were expected to orientate themselves after their arrival in front of the door at least for this long. All reported real-time assessments were added per participant for comparison. Figure 14 visualises movement speeds over time for all participants. Since a significant acceleration is searched for, speeds for the two non-startling events described in section 4.2.1 are displayed in the background as a baseline.

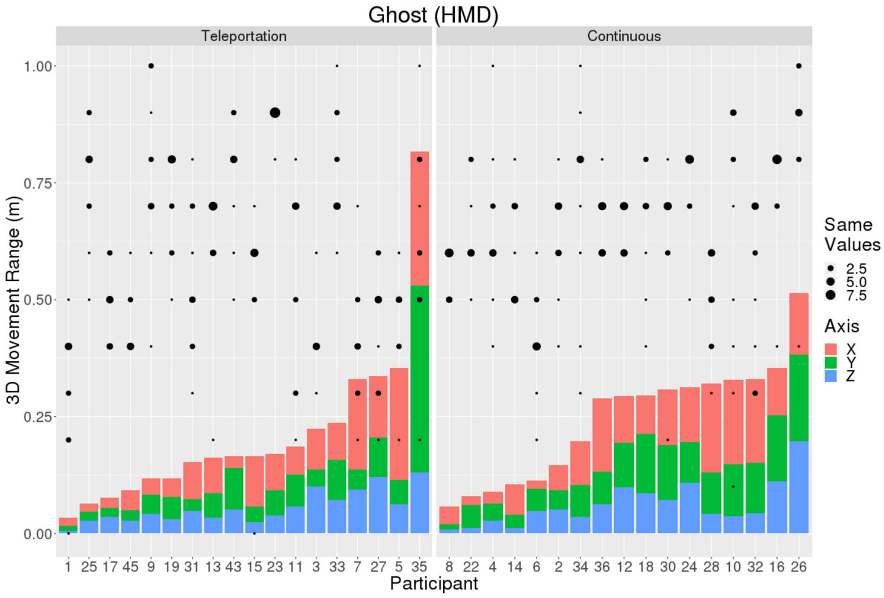


Figure 13: For each participant (n=35), faceted by locomotion group, this figure shows the dimensions of the head movement bounding box during the **ghost** special event, from second 2.5 to 10. Available real-time assessments were normalised and overlaid for comparison to real-time presence.

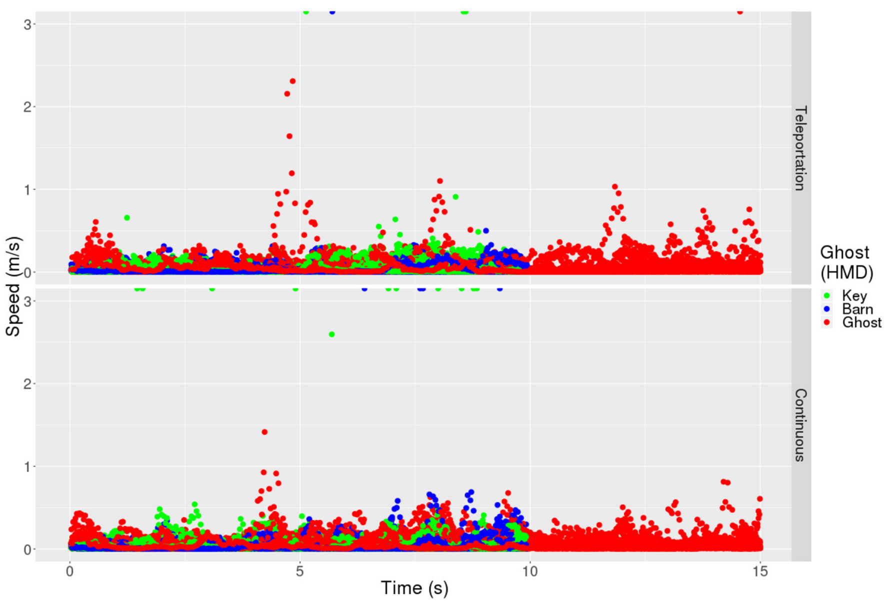


Figure 14: For the participants (n=35) in each of the two locomotion groups, this figure shows head movement speeds with samples of 25 frames per second during the **ghost** special event.

6 Discussion

A visual comparison of the head tracking data suggests no obvious difference between L_C and L_T in terms of the reactions observed for the **chandelier** and **ghost** special events. Figure 12 supports this for the **chandelier** special event. With a variety of progression patterns, it is difficult to determine how strong reactions on the chandelier were just by looking at individual lines. Overall, both groups contain about the same number of participants with high (>10 cm) and low (<10 cm) total travelled distance. Although participants from the L_C group reported higher absolute real-time presence in general (less magenta lines) and some of them featured clearer reactions, this could be due to individual variance in behaviour and should not be used as an argument without an appropriate baseline.

For the **ghost** special event, Figure 14 also supports the view that there is no difference between L_C and L_T. In both groups, several participants featured a clear acceleration with only marginal differences when compared to peaks in the baseline data. Figure 13 indicates smaller bounding boxes and less consistency within absolute real-time presence for L_T, which is an unexpectedly clear difference between the two locomotion groups. But similar to the total travelled distance metric of the **chandelier** special event, no justifiable baseline is available for the bounding box metric, making it difficult to put these observations into context.

However, at least for the presented visualisations of the **ghost** special event, it is possible to visually pinpoint possible reaction thresholds for movement 'range' (sum of all three bounding box dimensions) and movement speed: For the ranges in Figure 13, there is a noticeable jump between participants 33 and 7 for L_T and participants 34 and 36 for L_C. For the speeds in Figure 14, red peaks clearly represent unusual acceleration. It is hypothesised that participants with a range value greater than 25 centimetres or a speed value greater than 0.5 metres per second reacted to the **ghost** special event. With these two tests, participants can be assigned to three new groups, depending on whether they 'passed' both, one or none.

Table 2 shows a comparison of relevant meta data for each of the three reaction groups, considering the following factors:

- Self-reported experience with video games and virtual reality
- A single general rating of the overall experience of playing through the experiment on a scale ranging from 0 (poor) to 10 (excellent)

- Reported real-time presence, both for all reported values (percentage) and for the **ghost** special event specifically

Table 2: A comparison of relevant meta data for the **ghost** special event. The considered factors are experience with video games and VR (7-point), a rating of the experiment scenario (11-point) and real-time presence. By visually estimating a reaction threshold for range and speed of head movements, participants were grouped by reaction.

	Range and speed		Range or speed		No reaction	
	M	SD	M	SD	M	SD
Exp. (Games)	5.33	0.82	5.64	0.63	5.38	0.86
Exp. (VR)	2.00	1.55	3.14	2.03	2.86	1.68
Rating	7.33	3.08	6.79	2.12	6.76	1.92
Pres. (total %)	64.22	15.11	61.04	12.73	60.8	14.47
Pres. (**ghost**)	7.50	1.58	6.91	1.43	6.74	1.63

When comparing the rating and presence means between reaction groups, the expected hierarchy becomes apparent. Participants who reacted more to the **ghost** special event rated their experience higher and reported higher levels of presence not only during the whole experiment, but also before and after they encountered the ghost. In line with this, the experience means are lowest for participants who reacted most. This suggests that the visually determined thresholds are reasonable.

Considering the standard deviations in Table 2 in comparison to the actual differences in means, it might even indicate that the startle reflex through *social presence* as a behavioural measure has the potential to be more objective and reliable than self-reported real-time measures, as it would not have been possible to establish the three reaction groups just from experience, rating and real-time presence values.

Although the effect of other factors on this result (for example the research environment) cannot be discounted, this could be a promising approach for non-intrusively, more objectively and more reliably measuring presence in similar virtual environments. This could also be a very interesting starting point for future research on behavioural measures of presence.

7 Future Work

Further research could investigate the startle reflex through *social presence* as a behavioural measure of presence, and specifically search for influences by external factors. It could also refine the procedure of manually determining appropriate reaction thresholds for each metric and establish standardised procedures which could be used to analyse tracking data automatically.

While the two non-startling baseline events (see section 4.2.1) could be used as a baseline for the speed analysis, no baselines were used for the analysis of total travelled distance and range, which makes the results for these two metrics less comprehensive. But by nature, they are less suited for comparison, as random behaviour like looking around would be more likely to pollute the baseline. It is safer to predict no significant accelerations for a certain situation. Further research could investigate approaches to collecting reliable baseline data for other metrics than speed.

Some inconsistencies with the total reported presence values also raise new questions: In Figure 12, several lines with high total presence (cyan) feature a reaction below average and others with low total presence (magenta) feature a comparatively strong reaction. Similarly, Figure 13 shows outliers in real-time presence for participants 6, 34 and 28 in L_C and most participants in L_T. It is difficult to tell whether the subjective or behavioural measures reflect reality more precisely—something that could be examined in detail.

A within-subjects design could be used to cope with the large individual variance in behaviour, and evaluate whether the startle reflex in response to *social presence* can be successfully evoked more than once per participant in the same virtual environment. Lastly, it could be investigated whether the strength of the startle reflex depends on the type of stimulus used—the ghost was chosen carefully for this case-study, but its distance to participants could have had a greater influence on their reaction than its appearance.

The presented approach of measuring presence by analysing head movement tracking data could be relevant for further research in this field. Although the procedure of determining reaction thresholds would need validation in other contexts, this seems to provide a useful measure of presence for virtual environments in which it is possible to integrate a *social presence* special event. Head movement speeds and bounding box dimensions of the whole trajectory proved to be helpful when searching for a startle response.

References

[BRSJ+04] S. Bouchard, G. Robillard, J. St-Jacques, S. Dumoulin, M. J. Patry, and P. Renaud. Reliability and validity of a single-item measure of presence in vr. In *Proceedings. Second International Conference on Creating, Connecting and Collaborating through Computing*, pages 59–61, 2004.

[DHJM15] C. Deniaud, V. Honnet, B. Jeanne, and D. Mestre. An investigation into physiological responses in driving simulators: An objective measurement of presence. In *Science and Information Conference (SAI)*, pages 739–748, 2015.

[HMWA18] M. P. Jacob Habgood, David Moore, David Wilson, and Sergio Alapont. Rapid, continuous movement between nodes as an accessible virtual reality locomotion technique. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pages 371–378. IEEE, March 2018.

[HRC+03] Hunter G. Hoffman, Todd Richards, Barbara Coda, Anne Richards, and Sam R. Sharar. The illusion of presence in immersive virtual reality during an fmri brain scan. *CyberPsychology and Behavior*, 6(2):127–131, 2003.

[HWMA17] Jacob Habgood, David Wilson, David Moore, and Sergio Alapont. HCI lessons from PlayStation VR. In *Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play*, CHI PLAY '17 Extended Abstracts, pages 125–135, New York, NY, USA, 2017. ACM.

[Min18] The Steel Minions. The Chantry. [PS4 Digital Download], 2018.

[MIWP02] Michael Meehan, Brent Insko, Mary Whitton, and Jr Brooks Frederick P. Physiological measures of presence in stressful virtual environments. *ACM Transactions on Graphics*, 21(3):645–652, July 2002.

[MMK12] M. Mori, K. F. MacDorman, and N. Kageki. The uncanny valley [from the field]. *IEEE Robotics Automation Magazine*, 19(2):98–100, June 2012.

[NHW00] Sarah Nichols, Clovissa Haldane, and John R. Wilson. Measurement of presence and its consequences in virtual environments. *International Journal of Human-Computer Studies*, 52(3):471, 2000.

[RKW01] Sharif Razzaque, Zachariah Kohn, and Mary C. Whitton. Redirected walking. In *Proceedings of EUROGRAPHICS*, volume 9, pages 105–106. Citeseer, 2001.

[SBW17] Richard Skarbez, Frederick P. Brooks, and Mary C. Whitton. A survey of presence and related concepts. *ACM Computing Surveys*, 50(6):1–39, November 2017.

[Sch18] Johannes Schirm. HCI experiments inside environmental narrative games: Expanding the REVEAL framework. Master's thesis, Sheffield Hallam University, 2018. This work is unpublished.

[SFR01] Thomas Schubert, Frank Friedmann, and Holger Regenbrecht. The experience of presence: Factor analytic insights. *Presence: Teleoperators and Virtual Environments*, 10(3):266–281, 2001.

[SG07] Mel Slater and Maia Garau. The use of questionnaire data in presence studies: Do not seriously likert. *Presence: Teleoperators and Virtual Environments*, 16(4):447–456, 2007.

[She92] Thomas B. Sheridan. Musings on telepresence and virtual presence. *Presence: Teleoperators and Virtual Environments*, 1(1):120–126, 1992.

[Sla04] Mel Slater. How colorful was your day? why questionnaires cannot assess presence in virtual environments. *Presence: Teleoperators and Virtual Environments*, 13(4):484–493, 2004.

[SSC10] Mel Slater, Bernhard Spanlang, and David Corominas. Simulating virtual environments within virtual environments as the basis for a psychophysics of presence. In *ACM SIGGRAPH 2010*, volume 29 of *SIGGRAPH '10*, page Article 92, New York, NY, USA, 2010. ACM.

[SSH+17] Agnieszka Sorokowska, Piotr Sorokowski, Peter Hilpert, Katarzyna Cantarero, Tomasz Frackowiak, and Khodabakhsh Ahmadi et al. Preferred interpersonal distances: A global comparison. *Journal of Cross-Cultural Psychology*, 48(4):577–592, 2017.

[SSU95] Mel Slater, Anthony Steed, and Martin Usoh. The virtual treadmill: A naturalistic metaphor for navigation in immersive virtual environments. In *Virtual Environments '95*, pages 135–148. Springer, 1995.

[SUS94] Mel Slater, Martin Usoh, and Anthony Steed. Depth of presence in virtual environments. *Presence: Teleoperators and Virtual Environments*, 3(2):130–144, 1994.

[SW10] Harvey Smith and Matthias Worch. What happened here? environmental storytelling. In *Game Developers Conference*, 2010.

[TW98] Stefan Thie and J Wijk. A general theory on presence: Experimental evaluation of social virtual presence in a decision making task. In *Presence in Shared Virtual Environments Workshop*, volume 1, 1998.

[UQO04a] UQO Cyberpsychology Lab. Revised immersive tendencies questionnaire 3.01. [Online] Last accessed: 26-Nov-2018, 2004.

[UQO04b] UQO Cyberpsychology Lab. Revised presence questionnaire 3.0. [Online] Last accessed: 26-Nov-2018, 2004.

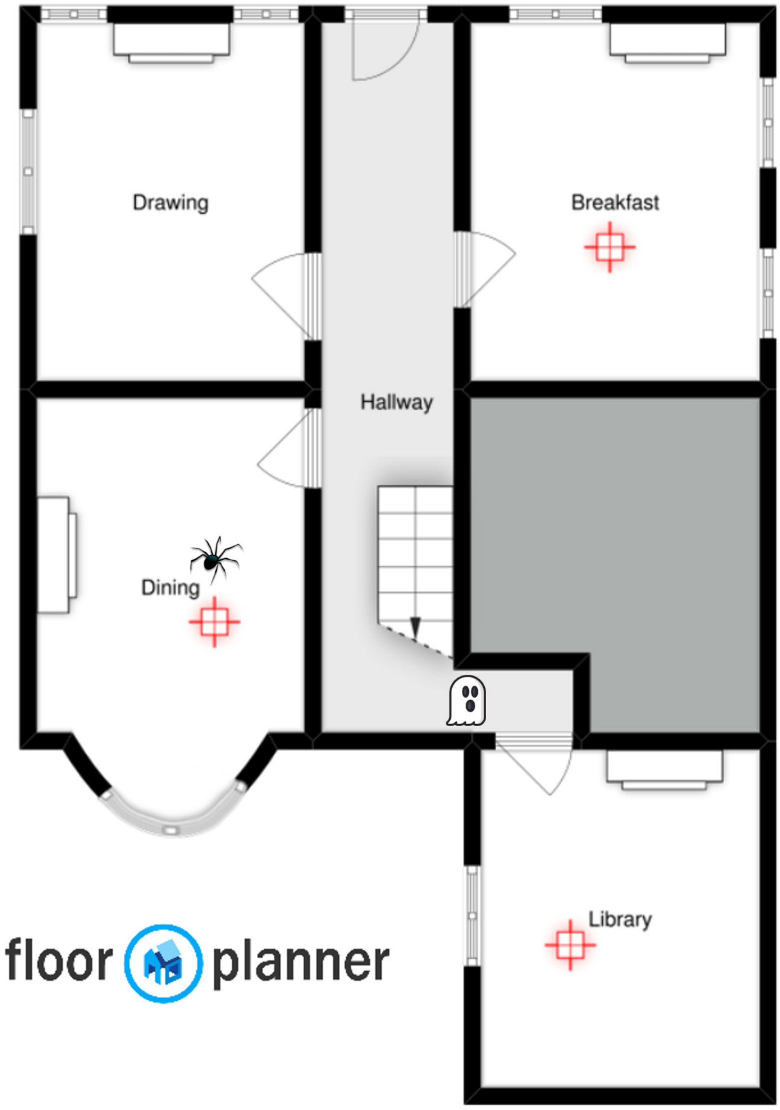
[WS98] B. G. Witmer and M. J. Singer. Measuring presence in virtual environments: A presence questionnaire. *Presence*, 7(3):225–240, June 1998.

List of Figures

List of Tables

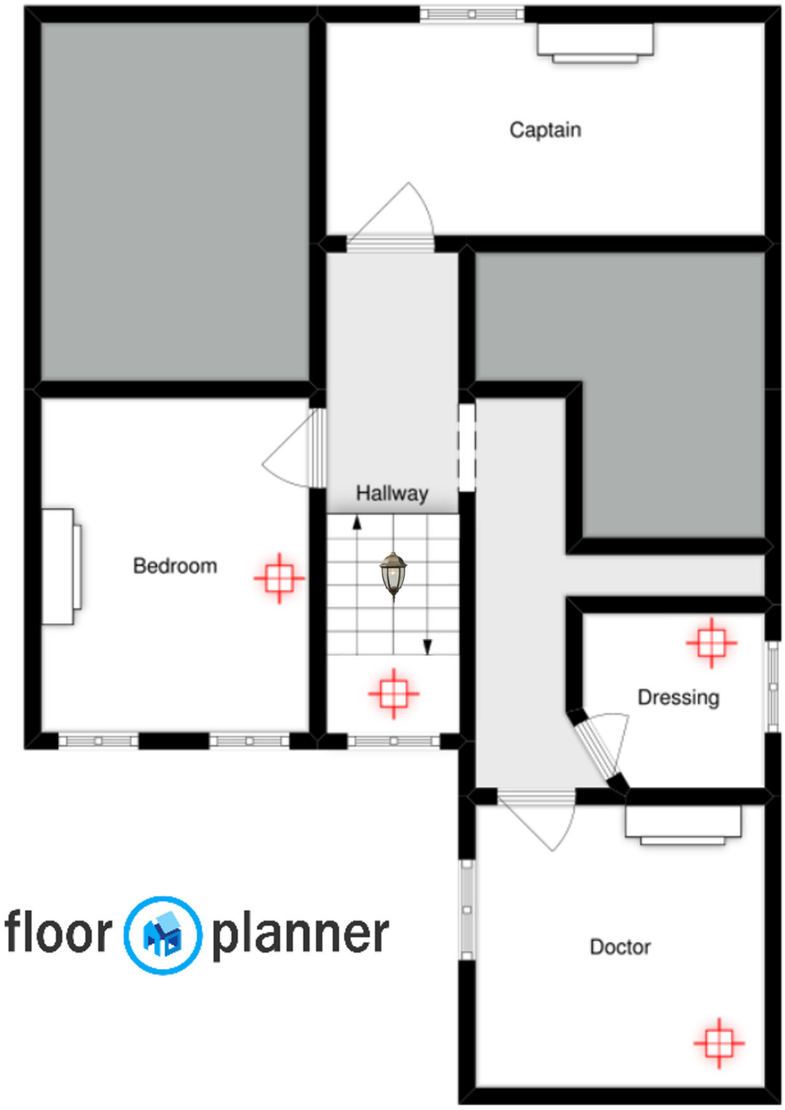
A Floor Plan

This document contains the floor plan of the house which the main task of the experiment had to be accomplished in. The positions of the seven hidden items are marked in red. The locations of the three special events are marked by a spider, ghost and chandelier symbol.



The **ground floor** with four accessible rooms and three items.

This floor plan was created with Floorplanner.com.



The **first floor** with four accessible rooms and four items.
The item at the staircase has to be unlocked by a special event.

This floor plan was created with Floorplanner.com.

B Locomotion Nodes

All locomotion nodes were renamed for the experiment. Separated by underscores, the different parts of the naming scheme identify the exact location of a node from left to right. Every name has to start with 'Node_', followed by one of four main areas: 'Graveyard' or 'Garden' for places outside the house and 'Downstairs' or 'Upstairs' for places inside the house. The following list shows all nodes that were accessible during the experiment:

```
Node_Graveyard_Grave
Node_Graveyard_Centre
Node_Graveyard_Obelisk
Node_Graveyard_Statue_Way_1
Node_Graveyard_Statue_Way_2
Node_Graveyard_Statue
Node_Graveyard_Dalkeith
Node_Graveyard_Barn_Way_1
Node_Graveyard_Barn_Way_2
Node_Graveyard_Barn_Way_3
Node_Graveyard_Barn_Way_4
Node_Graveyard_Barn_Way_5
Node_Graveyard_Barn
Node_Graveyard_Entrance_Way_1
Node_Graveyard_Entrance_Way_2
Node_Graveyard_Entrance_Way_3
Node_Graveyard_Entrance
Node_Garden_Statue_Way_1
Node_Garden_Statue_Way_2
Node_Garden_Statue
Node_Garden_House_Way_1
Node_Garden_House_Way_2
Node_Garden_House
Node_Downstairs_Hallway_Entrance
Node_Downstairs_Hallway_Front
Node_Downstairs_Hallway_Centre
Node_Downstairs_Hallway_Back
Node_Downstairs_Hallway_End
Node_Downstairs_DrawingRoom_Entrance
Node_Downstairs_DrawingRoom_Sofa
Node_Downstairs_DrawingRoom_Paintings
Node_Downstairs_DrawingRoom_Fireplace
Node_Downstairs_DrawingRoom_Desk
Node_Downstairs_BreakfastRoom_Entrance
Node_Downstairs_BreakfastRoom_Globe
Node_Downstairs_BreakfastRoom_Fireplace
Node_Downstairs_BreakfastRoom_Back
Node_Downstairs_BreakfastRoom_Centre
Node_Downstairs_DiningRoom_Entrance
Node_Downstairs_DiningRoom_Table
Node_Downstairs_DiningRoom_Fireplace
Node_Downstairs_DiningRoom_Window
Node_Downstairs_Library_Entrance
Node_Downstairs_Library_Fireplace
Node_Downstairs_Library_Back
Node_Downstairs_Library_Window
Node_Downstairs_Upstairs_Way_1
Node_Downstairs_Upstairs_Way_2
Node_Downstairs_Upstairs_Way_3
Node_Upstairs_Hallway_Centre
Node_Upstairs_Hallway_Front
Node_Upstairs_Hallway_End_Way_1
Node_Upstairs_Hallway_End_Way_2
Node_Upstairs_Hallway_End
Node_Upstairs_BestBedroom_Entrance
Node_Upstairs_BestBedroom_Centre
Node_Upstairs_BestBedroom_Window
Node_Upstairs_BestBedroom_Back
Node_Upstairs_BestBedroom_Exit
Node_Upstairs_CaptainJennersRoom_Entrance
Node_Upstairs_CaptainJennersRoom_Centre
Node_Upstairs_CaptainJennersRoom_Desk
Node_Upstairs_CaptainJennersRoom_ChestOfDrawers
Node_Upstairs_DressingRoom_Entrance
Node_Upstairs_DressingRoom_Centre
Node_Upstairs_DrJennersRoom_Entrance
Node_Upstairs_DrJennersRoom_Fireplace
Node_Upstairs_DrJennersRoom_Desk
Node_Upstairs_DrJennersRoom_Window
```

C Game Script

This document summarises the complete game progression of the experiment.

Audio recordings last 15 seconds. The script will list named 'markers' which are automatically issued at certain points in the storyline. With average playing speed, the main task should ideally take between eight and ten minutes.

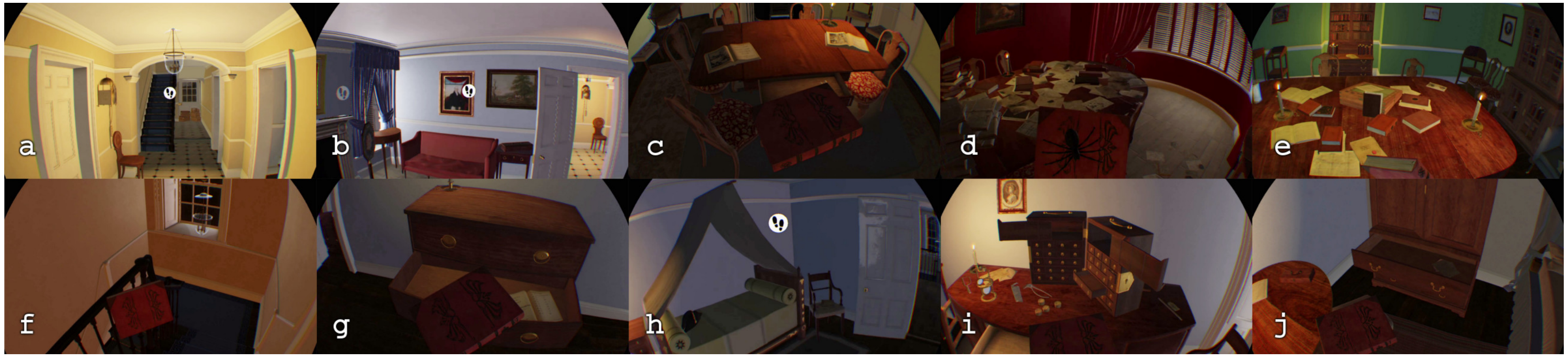


Figure 1: These (brightened) screen captures are used to reference specific rooms or items in the script.

Event or Marker	Description	Comment
Instruction	*Welcome to virtual reality! I'm Johannes from Germany, and I'll be guiding you through a mysterious world for a few minutes. But first, let's check if your controller is working properly.*	Phase: **Preparation** (0)

Instruction	*Please tilt the left joystick to the left and simultaneously the right joystick to the right.*	Repeats after 10 seconds
Instruction	*Great! You're almost ready to go now. There is just one more thing for you to know before we start.*	When controller joysticks are tilted as described above
Instruction	*Within the next few minutes, I will ask you how present you feel in the world that you are seeing. By 'present' I mean the extent to which you feel as if you were really there. Whenever you hear me asking this question, please speak out loud a number ranging from zero to ten. Zero means no presence and ten that you feel being part of the scene. Your answer will be recorded by the microphone in the headset you are wearing right now. If anything is unclear to you, just wait a few seconds, I'll repeat it for you. Otherwise, press one of the buttons near your right thumb to start!*	Repeats after 10 seconds
Instruction and audio recording	*On a scale from zero to ten, to which extent do you feel present in the scene?*	When one of the symbol buttons is pressed
`Preparation`	Controller check from trigger to fade-out.	
Instruction	*You have just woken up at this place. Feel free to have a look around, but remember to not leave the tracking area by taking steps or turning around. Instead, use one of the joysticks to rotate your view.*	Phase: **Adaptation** (1)
`Adaptation_VR`	First look around from fade-in to locomotion system activation.	

Instruction	*Can you see the little footstep icon? You can navigate to its location by simply looking at it and pressing one of the buttons near your right thumb.*	
Instruction	*Do you feel like someone else is around, as well? Let's examine this place a little bit...*	Delayed by 4 seconds to simulate a short moment of 'sensing' that there is someone else

The following part of the story is optional and depends on the area the participant examines first:

Event or Marker	Description	Comment
`Adaptation_Barn_Locked`	Walk to barn from locomotion system activation to locked barn door.	
Instruction	*This door seems to be locked. There has to be a key somewhere on the graveyard...*	When trying to open the barn's door without having found the key

But it is possible to directly head to the statue and collect the key needed to open the barn's door:

Event or Marker	Description	Comment
`Adaptation_Statue_Examine`	Walk to statue from locomotion system activation or locked barn door to statue examination.	

Tracking	As a first test recording, the participant's movements when picking up the key are recorded here. This could show if participants noticed that they can actually examine items with their hands.	Head and hands are recorded for 10 seconds at 25 frames per second
`Adaptation_Key_PickUp`	Statue interaction from examination to key pick-up.	
Instruction	*When you collect an item, you have a few moments to examine it in your hands before it gets stowed into your bag.*	When starting to examine the key
Instruction and audio recording	*On a scale from zero to ten, to which extent do you feel present in the scene?*	2 seconds after the key was put away
`Adaptation_Barn_Unlocked`	Walk to barn from key pick-up to unlocked barn door.	
Tracking	As a second test recording, the participant's movements when looking into the barn are recorded here. This could show to which degree participants change their position for a better view.	Head and hands are recorded for 10 seconds at 25 frames per second
`Adaptation_Barn_Ghost`	Barn interaction from unlocked door to ghost examination.	
Instruction	*Where is she going? Let's follow her!*	2 seconds after the ghost was examined
Instruction and audio recording	*On a scale from zero to ten, to which extent do you feel present in the scene?*	When the participant begins to follow the ghost
`Adaptation_End`	End of adaptation from ghost examination to fade-out.	

Instruction	*Maybe this is what the ghost wanted us to see? It seems like some books went missing!*	Phase: **Task** (2) When empty book frames at the statue are examined
`Task_Arrival`	Walk to statue from fade-in to end of statue examination.	
`Task_House_Entry`	Walk to house from end of statue examination to arrival in the hallway.	

From here, participants can choose their path through the house. Figure 1a shows the hallway in which participants arrive. All of the following sections are intended to be played in one piece, although the game technically does not prevent participants from leaving a room without triggering the intended interactions and coming back later. No item can be found in the drawing room, which is shown in Figure 1b.

Event or Marker	Description	Comment
`Task_DrawingRoom_Enter`	Walk to drawing room from arrival in the hallway or last item pick-up to first entry.	The door to the drawing room is already opened to make it more likely for participants to go there first
Instruction and audio recording	*On a scale from zero to ten, to which extent do you feel present in the scene?*	2 seconds after the drawing room was first entered
`Task_DrawingRoom_Leave`	Drawing room examination from first entry to return to the hallway after finding no item.	This is one of two rooms where no item can be found

In the breakfast room, which is shown in Figure 1c, the table drawer contains a book.

Event or Marker	Description	Comment
`Task_BreakfastRoom_Door`	Walk to breakfast room from arrival in the hallway or last item pick-up to opened door.	
`Task_BreakfastRoom_Item`	Breakfast room examination from door opening to item pick-up.	
Instruction	*Oh, this book looks like the one we saw at the statue! Let's search for the others.*	Played for the first book collected in the house

The dining room is shown in Figure 1d. Participants pick up the book with the spider on it from its table.

Event or Marker	Description	Comment
`Task_DiningRoom_Enter`	Walk to dining room from arrival in the hallway or last item pick-up to first entry.	The door to the dining room is already opened to make it more likely for participants to go there first
`Task_DiningRoom_Item`	Dining room examination from first entry to item pick-up.	This item has the spider on it
Tracking	The participant's movements when examining the book with the spider on it are recorded here. Some kind of reaction with the hands is expected.	Head and hands are recorded for 10 seconds at 25 frames per second
Instruction	*That's another book! Five more to go.*	Played for the second book collected in the house
`Task_DiningRoom_Spider`	Spider event from item pick-up for ten seconds.	Automatically triggered 10 seconds after item pick-up

Instruction and audio recording	*On a scale from zero to ten, to which extent do you feel present in the scene?*	2 seconds after the book with the spider was put away

After participants have encountered the ghost in front of the library door, they have to interact with it in order to continue. The ghost then hovers through the wall, unlocking the door with a clicking sound. In the library, participants pick up a book from the table, which is shown in Figure 1e.

Event or Marker	Description	Comment
`Task_Ghost_Arrival`	Walk to library from arrival in the hallway or last item pick-up to locked library door.	After three seconds, the ghost will appear behind the participant who will be almost finished examining the locked library door
Tracking	The participant's movements when turning around and facing the ghost are recorded here. A strong reaction with the head is expected.	Head and hands are recorded for 20 seconds at 25 frames per second
`Task_Ghost_Door`	Ghost event from arrival at locked door to door opening.	The ghost unlocked the door to the library and the participant opened it
`Task_Ghost_Item`	Library examination from door opening to item pick-up.	
Instruction	*Nice, you found the third book! Four books remain.*	Played for the third book collected in the house
Instruction and audio recording	*On a scale from zero to ten, to which extent do you feel present in the scene?*	5 seconds after the library was left

When walking past the staircase, which is shown in Figure 1f, participants should discover the rope mechanism sooner or later. It can only be activated from the middle of the staircase. The locomotion system is then temporarily disabled to prevent participants from walking away while the special event is played back.

After the chandelier swung towards them, participants hear a book falling onto the floor. The book appears in parallel, which they are then able to pick up from any locomotion node near the staircase. If they leave the middle of the staircase without collecting it, a gentle hint is played to them.

Event or Marker	Description	Comment
`Task_Chandelier_Examine`	Walk to stairs from arrival in the hallway or last item pick-up to chandelier examination.	Blocks access to adjacent locomotion nodes for the duration of the event
Tracking	The participant's movements when realising that the chandelier is swinging towards them are recorded here. A uniform reaction with head and hands is expected.	Head and hands are recorded for 10 seconds at 25 frames per second
`Task_Chandelier_Reminder`	Chandelier event from examination to progression to an adjacent node.	This marker is optional, since the book can already be picked up on the staircase
Instruction	*Did you hear a book falling onto the ground, too? Maybe we discovered something unexpected by breaking the chandelier...*	Only played if the book on the staircase was not yet collected
`Task_Chandelier_Item`	Chandelier event from examination or reminder to item pick-up.	
Instruction	*Well done, that's the fourth book! Just three more to find!*	Played for the fourth book collected in the house

In the best bedroom, which is shown in Figure 1g, a book can be found inside a chest of drawers.

Event or Marker	Description	Comment
`Task_BestBedroom_Enter`	Walk to best bedroom from arrival in the hallway or last item pick-up to first entry.	The door to the best bedroom is already opened to make it more likely for participants to go there first
Instruction and audio recording	*On a scale from zero to ten, to which extent do you feel present in the scene?*	2 seconds after the best bedroom was first entered
`Task_BestBedroom_Item`	Best bedroom examination from first entry to item pick-up.	
Instruction	*Great! Five books found and only two more to go.*	Played for the fifth book collected in the house

No item can be found in Captain Jenner's room, which is shown in Figure 1h.

Event or Marker	Description	Comment
`Task_CaptainsRoom_Door`	Walk to captain Jenner's room from arrival in the hallway or last item pick-up to opened door.	
`Task_CaptainsRoom_Leave`	Captain Jenner's room examination from door opening to return to the hallway after finding no item.	This is one of two rooms where no item can be found
Instruction and audio recording	*On a scale from zero to ten, to which extent do you feel present in the scene?*	2 seconds after Captain Jenner's room was first left

In the dressing room, which is shown in Figure 1i, a book can be found inside a medicine chest.

Event or Marker	Description	Comment
`Task_DressingRoom_Enter`	Walk to dressing room from arrival in the hallway or last item pick-up to first entry.	The door to the dressing room is already opened to make it more likely for participants to go there first
`Task_DressingRoom_Item`	Dressing room examination from first entry to item pick-up.	
Instruction	*Brilliant, now there's only one book left!*	Played for the sixth book collected in the house

In Dr Jenner's room, which is shown in Figure 1j, a book can be found inside the drawer of a wardrobe.

Event or Marker	Description	Comment
`Task_DrJennersRoom_Door`	Walk to Dr Jenner's room from arrival in the hallway or last item pick-up to door opening.	
Instruction and audio recording	*On a scale from zero to ten, to which extent do you feel present in the scene?*	2 seconds after the door to Dr Jenner's room was opened
`Task_DrJennersRoom_Item`	Dr Jenner's room examination from door opening to item pick-up.	
Instruction	*What a good job you did finding all the missing books!*	Played for the final book collected in the house

After finding the seven missing books, all participants experience the same script in the same order again. Wherever they are in the house, they are teleported back to the statue in the front garden, which now has a book in each stone frame. They are thanked for their participation and asked to give one last presence measure before the game automatically jumps back to the main menu and writes the audio file with all recordings in it.

Event or Marker	Description	Comment
Instruction	*Thank you for finding all seven books!*	
Instruction and audio recording	*On a scale from zero to ten, to which extent do you feel present in the scene?*	1 second after the last sentence was spoken
Instruction	*We hope you enjoyed the experience. Please don't forget to complete the questionnaire after you take off the headset.*	5 seconds after the end of the last presence measurement question—although audio recording will still last 10 seconds in total for very slow participants
`End`	Ending event from last item pick-up to the end of the experiment.	

D Participants

This document records which data is available for which participant. Participants with even numbers used continuous locomotion, participants with odd numbers used teleportation. The game automatically adjusted the locomotion system for each group. In the table below, rows for the teleportation group are highlighted in light grey.

Quite some participants were not able to respond to all real-time assessments, in which case there will not be a tick in the corresponding table cell. However, some participants completed the subtasks of the main task in an order and speed that made two successive measurements overlap—skipping one of them due to the question already being asked. In this case, they still answered all questions and were able to produce a complete dataset, but one or even two measurements were not even taken by the experiment application. Such cases are marked by a dash in the corresponding table cell. Some numbers remained unused because of group balancing.

Number	Complete	Remarks	Game	Questionnaire	Real-time assessments									
					1	2	3	4	5	6	7	8	9	10
1	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3		1 assessment skipped	✓	✓		✓		✓	✓		✓	✓	✓	–
4	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5			✓	✓			✓		✓	✓	✓	✓	✓	✓
6	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
8	✓	1 assessment skipped	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
9	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
11	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12	✓	1 assessment skipped	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
13	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
14			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
15	✓	1 assessment skipped	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–

16	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
17	✓	1 assessment skipped	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
18	✓	2 assessments skipped	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–	–
19	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
20				✓										
21														
22			✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
23	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
24	✓	1 assessment skipped	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
25	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
26	✓	1 assessment skipped	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
27	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
28	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
29														
30	✓	1 assessment skipped	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
31	✓	Talked with others	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
32	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
33	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
34	✓	Talked with others	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
35			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
36	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
37														
38				✓										
39		2 assessments skipped	✓		✓	✓	✓	✓	✓	✓	✓	✓	–	–
40														
41		1 assessments skipped	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	–
42														
43	✓	1 assessments skipped	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
44														
45			✓	✓				✓	✓	✓	✓	✓	✓	✓

Hochschule Reutlingen
Reutlingen University

Erklärung zur Abgabe einer Bachelor- / Master-Thesis

Ich versichere ehrenwörtlich, dass ich

- die abgegebene Thesis selbständig verfasst habe,
- alle benutzten Quellen und Hilfsmittel - dazu zählen auch sinngemäß übernommene Inhalte, leicht veränderte Inhalte sowie übersetzte Inhalte - in Quellenverzeichnissen, Fußnoten oder direkt bei Zitaten angegeben habe,
- alle wörtlichen und sinngemäßen Zitate von Textstücken, Tabellen, Grafiken, Fotos, Quellcode usw. aus fremden Quellen als solche gekennzeichnet und mit seitengenauen Quellenverweisen versehen habe,
- die von mir eingereichten Dokumente und Artefakte noch nicht in dieser oder ähnlicher Form einer anderen Kommission zur Prüfung vorgelegt wurden,
- alle nicht als Zitat gekennzeichneten Inhalte selbst erstellt habe und dass ich
- den „Leitfaden für gute wissenschaftliche Praxis im Studiengang MKI“[1] kenne und achte.

Mir ist bekannt, dass unmarkierte und unbelegte Zitate und Paraphrasen Plagiate sind und nicht als handwerkliche Fehler, sondern als eine Form vorsätzlicher Täuschung der Prüfer gelten, da fremde Gedanken als eigene Gedanken vorgetäuscht werden mit dem Ziel der Erschleichung einer besseren Leistungsbewertung.
Mir ist bekannt, dass Plagiarismus die Standards guter wissenschaftlicher Praxis, die Regeln des Studiengangs Medien- und Kommunikationsinformatik, die Studien- und Prüfungsordnung der Hochschule Reutlingen (§ 10 Täuschung und Ordnungsverstoß) und das Landeshochschulgesetz von Baden-Württemberg (§ 3 Wissenschaftliche Redlichkeit Abs. 5, § 62 Exmatrikulation Abs. 3) missachtet und seine studienrechtlichen Folgen vom Nichtbestehen bis zur Exmatrikulation reichen.
Mir ist auch bekannt, dass Plagiate sogar das Urheberrechtsgesetz (§ 51 Zitate, § 63 Quellenangabe, § 106 Unerlaubte Verwertung urheberrechtlich geschützter Werke) verletzen und zivil- und strafrechtliche Folgen nach sich ziehen können.

Nachname: ____

Vorname: ____

Matrikelnummer: ____

Datum: ____

Unterschrift: ____

---

[1] https://bscwserv.reutlingen-university.de/bscw/bscw.cgi/d2871027/GWP.pdf