Research Proposal

Evaluating Locomotion in Virtual Reality Through Presence

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Contents

1 Introduction

Habgood, Moore, Wilson and Alapont (2018) presented an alternative approach to player locomotion in stationary virtual reality setups that aimed to keep the user oriented and increase their presence in comparison to other techniques involving teleportation. However, no differences were found in the reported levels of presence between the tested conditions — the authors concede that this could be due to the way presence was measured in their study (pp. 6–7). Over the last few decades, the research community discussed many objective measures of presence and how these could be combined with subjective measures, providing as many opportunities to improve this locomotion study through a more direct measurement of presence.

Further investigating this novel locomotion technique would be beneficial for all developers of immersive virtual environments (IVEs) who are working with stationary setups. In fact, it is very rare for virtual reality setups to allow the user to walk around freely, which creates the problem of having to map locomotion controls from the most natural system (simply by taking steps in the desired direction) onto an abstract system like pressing buttons on a controller or additionally interacting with a user-interface for most contemporary implementations. Especially in the emerging entertainment industry, there is always the need to make a compromise in order to develop cutting-edge technology that is still affordable for the wider market. Although many innovations have recently made virtual reality more accessible for consumers, there are still some quite fundamental problems that need to be solved, mostly with regards to human perception. Motion sickness — primarily caused in IVEs by a discrepancy between visual and vestibular sensations — is one of them.

A common approach to avoid this problem with stationary setups is to teleport the user to key locations and let them examine their surroundings just through head and torso movements. Instead of teleporting the user in the blink of an eye, the proposed technique by Habgood et al. (2018) linearly translates the user's base position to the target location with a short, rapid movement. Interestingly, participants reported significantly lower levels of motion sickness both for teleportation and the rapid movement compared to free control over their base position (p. 5). This means that if users were to experience higher levels of presence with the rapid movement technique than with teleportation, this approach would demonstrably be preferable to the commonly implemented teleportation. The results of the corresponding study did unfortunately not confirm this thesis.

However, the authors state that they only used the presence questionnaire by Witmer and Singer (1998) and had to remove 75 % of the questions because they did not apply to the IVE the study was conducted with. Using subjective measures of presence has been a controversial subject in literature for many years now. Slater (2004) argued that the concept of presence itself is something presence researchers made up in their head — and, in fact, there is still no model everybody agrees on. Nonetheless, as Skarbez, Brooks and Whitton (2017) showed in a recent literature survey, it is indeed possible to significantly increase the comprehensiveness of presence measurements by carefully combining subjective and objective measures. This can be a quite sophisticated task, as objective measures of presence usually depend on the specific IVE they are used with and need to be interpreted correctly.

The project outlined in this research proposal would build upon the original study designed by Habgood et al. (2018) and incorporate a more detailed IVE that would provide users with more context than the previous IVE did, as well as a combination of subjective and objective measures of presence, specifically selected for this context. The main hypothesis would still be that participants experience higher levels of presence in the IVE when using the novel locomotion technique with rapid movements between nodes instead of immediate teleportation. With a refined method of presence measurement, the results of the new study are expected to provide proof corroborating this hypothesis. This would contribute an important insight to the field of virtual reality — potentially helping the people of this large community of researchers and developers to create more compelling IVEs.

2 Methodology

As a follow-up study to the work by Habgood et al. (2018), from now on referred to as 'the original study', the proposed study will have many things in common with the original study. Instead of repeating methodical details that are likely to stay the same, this section will primarily be concerned about what would be different from the original study and the reasoning behind this. Appropriate methods for presence measurement will only be determined as part of the project (see section 3), as these need to be carefully considered and will also depend on more specific questions about what can be implemented. Still, a first summary of the most promising methods will already be included in section 2.2. This will provide a starting point and make it easier to estimate which methods would best fit the study.

2.1 Design Considerations

The original study showed that participants who could freely control their base position in the IVE experienced a significantly higher level of motion sickness. Since there were almost no advantages of this method (except for experts feeling more in control), the proposed study will only compare the rapid movement technique with teleportation. For the latter, participants had to place a basic avatar representation of themselves at the location they wanted to be teleported to. Their head rotation was mapped onto a two-dimensional position space representing the floor. Although this system was chosen 'because of its ubiquity on Oculus and Vive platforms' (p. 3) and was expected to be intuitive and provide greater precision (p. 7), the usability analysis showed that it had the lowest scores for ease of use and was more difficult to understand than the other systems (p. 7). The authors propose to improve the teleportation system for future studies, but it is argued in this proposal that it should be replaced by a node-based system.

The main reason for this is that in terms of user interaction with the IVE, there is too much of a difference between the two systems. This can be most clearly deduced from the recorded timings: Participants needed on average more than 1.5 times the time for executing their tasks using teleportation than they needed for doing the same with the node-based system. But apart from giving them more overall time to experience the IVE, the teleportation system also made them actively place the avatar in their environment, which seems require a much better sense of it before even performing any actions. Depending on the model that is used to understand and define presence, this can make an important difference — especially because the sought-after difference in presence might be relatively subtle. It would therefore make sense to remove any differences between the two systems except for the rapid movement, which is the primary subject of this research. Alternatively, if the results would need to be directly comparable to contemporary implementations, the avatar placement could be applied to the rapid movement condition without changing the teleportation system.

One last aspect worth thinking about is what type of experimental design should be followed. In the original study, two groups of participants were gathered in order to both test (VR) gaming novices and experts. Furthermore, it implemented the within-subjects design, so that all participants experienced all locomotion techniques. Depending on the chosen measures of presence, learning could have an impact on the second condition, which would pose a serious threat to internal validity.

MacKenzie (2013, pp. 175–187) explains the general assets and drawbacks of each approach. Implementing the between-subjects design where participants would only experience one locomotion technique would allow to completely hide the fact that the experiment actually tests two separate locomotion techniques. Participants could focus more on actually engaging with the IVE as a main task, which would logically lead to a much more natural response on the presence measurements. To leave them time to adapt themselves to the general feeling of being in virtual reality, calm down and potentially forget about fact that they participate in a closely controlled experiment, they could be introduced to their respective locomotion technique outside the area they will have to accomplish the tasks in — potentially justified by a small story that provides reasoning for the tasks, as well. On the other hand, this design would provide less data for each participant and could weaken the results when faced with the argument of predisposition.

2.2 Presence Measurement

Reliably measuring presence is a very sophisticated task and no methods exist until now that are neither subjective measures nor closely linked to specifics of the IVE they are collected in. However, in a recent literature survey by Skarbez et al. (2017), the authors 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.' (p. 96:32). Following this advice is expected to make the results of the proposed study comprehensive enough to answer the research question.

Three main categories of presence measures are currently discussed and used within the literature: Subjective measures by directly letting the participant answer questions, physiological measures and behavioural measures. Slater, Spanlang and Corominas (2010) have presented a psychophysical evaluation of the most important factors contributing to presence for specific setups, but it is important to note that this work does not provide psychophysical measures of presence itself. Almost all other approaches can be assigned to one of the three mentioned categories. In the following subsections, each of them is explained in more detail and the most appropriate implementations for each category are considered for the proposed study.

2.2.1 Subjective

The difficulty with subjective measures lies in the concept of presence used to design questions and the way these are understood by the participants. Slater (2004) compared this to asking a person how 'colourful' yesterday was for them. Still, there are many questionnaires available that have been shown to be 'valid, sensitive, and reliable' (Skarbez et al., 2017, p. 96:28).

Most of these are post-questionnaires, summarising the participant's whole experience in the IVE. The ones by Slater, Usoh and Steed (1994) and Witmer and Singer (1998) are most commonly used, as well as the Igroup Presence Questionnaire Schubert, Friedmann and Regenbrecht (2001). To address the issue of them not assessing presence in real-time, it could be worth considering the 1-item instrument presented by Bouchard et al. (2004), which is reported to be working surprisingly well because 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' (Skarbez et al., 2017, p. 96:27).

For the proposed study, it seems like there would only be a minor difference between the post-questionnaires mentioned, as their sub-scales would all fit the IVE used. But since the single question by Bouchard et al. (2004) was reported to be working well with the presence questionnaire by Witmer and Singer (1998), it could be beneficial to combine these two in order to both collect post-experience data and subjective real-time measures. Still, further research on this approach and how to best integrate it into the experiment design is needed. This primarily regards how often and in which manner the 1-item measure should be retrieved and how it should be analysed.

2.2.2 Physiological

While physiological measures are the most objective ones and provide real-time data, they often require special equipment attached to the participant, which could potentially influence presence through distraction. They are most frequently used in studies featuring IVEs that 'are known to affect physiological signals in certain ways' (Skarbez et al., 2017, p. 96:31), for example threatening or stressful situations. For the proposed study — one that regards two different locomotion techniques which are expected to have a more subtle but continuous effect on presence — randomly integrating special events in order to trigger physiological reactions would yield the same

results for both conditions. However, Meehan, Insko, Whitton and P. (2002, p. 650) found that the difference in heart rate — the most distinct objective measure for them — even correlated to subjective measures taken through the questionnaire by Slater et al. (1994). It could therefore be considered as a validation of the post-questionnaire in the proposed study.

2.2.3 Behavioural

Skarbez et al. (2017, p. 96:32) think that 'behavioral measures represent a promising area of study that has so far been understudied' and point out that these measures can be integrated into virtually any IVEs in a relatively natural manner — unlike physiological measures — without disturbing the participant or making the experimental design too complex. Even though behavioural measures can seldom be compared between IVEs, they could be of great use for the proposed study. Head position and rotation could for example be captured during set key events such as an object at the ceiling 'accidentally' breaking loose from its mounting and swinging towards the participant or an unexpected spider sitting at the back of an object they were asked to investigate. Similar to the technique Slater, Usoh and Chrysanthou (1995) applied, the participant could additionally be asked to orient their head towards a place in the IVE they have visited before, indicating how well they perceived their environment. These measures could be quite seamlessly integrated into the IVE of the proposed study, but the same issue mentioned for physiological measures in section 2.2.2 could arise: Maybe these measures are not sensitive enough to reflect the presence levels in this study.

2.3 Experimental Design

In summary, the final experimental design depends on how exactly presence will be measured, which in turn depends on what will be feasible to integrate into the IVE. What can be said is the following: Participants would again be randomly selected from (VR) gaming novices (non-specialist adults) and experts (specialist 'digital natives'). This ensures external validity, since these two groups approximately represent both extremes of the spectrum of gaming and virtual reality exposure. After a short briefing, each participant would sign an appropriate informed consent form and fill out a demographic questionnaire, just like in the original study. As much as possible should be done through the user interface of the IVE, though, so all participants are instructed exactly in the same way.

They would learn how to use the locomotion system outside and then perform the actual tasks inside, which would prevent their learning from interfering with the mental model tested through behavioural measures and therefore strengthen internal validity. Three to six tasks could be connected by a little bit of story in order to keep the participants interested and create the conditions for them to naturally engage with the experience. Construct validity would primarily depend on the instruments that will be employed to measure presence, but they are expected to validate each other when carefully chosen. As always with experiments involving IVEs, participants will be able to abort at any time. Breaks should not be made, as they would introduce differences in experience between participants. More on the ethics of the proposed study can be found in the appendix.

3 Project Plan

In the appendix, a preliminary Gantt chart is presented for the proposed study. It is important to note that this was designed with the goal to carry out the study within the 2.5 months available, which is why the implementation itself was not planned to take up most of the time. Depending on the difficulty level of the implementation, this might not be realistic — especially since the game engine the IVE will be implemented with is know to be quite a technical challenge to work with. However, the IVE itself has already been realised in detail and an experimental system was implemented before in the same context. It could therefore be fair to assume that the implementation itself would only involve integrating parts of the old experiment system into the current IVE and enhancing it by additional measures of presence and real-time recordings. But without the necessary experience, this estimation is admittedly a weaker point of the project plan.

Still, expecting the implementation (about one month in the Gantt chart) to take twice the time that would presumably be needed to accomplish the same in one of the common game engines like Unity or Unreal seems like a realistic estimation. The yellow symbols in the Gantt chart symbolise the most important milestones: After one week in the project, the final methods of measuring presence should be decided on. Three weeks after that, at least the basic functionality of the experiment scenario should have been implemented. The subsequent two weeks should be used to test and improve the IVE, which naturally needs to be completed when the experiment is officially approved. In the remaining time, participants should actively be

contacted and made appointments with before starting to actually conduct the experiment. This will allow the last phase to be solely concentrated on testing participants and keeping the procedure consistent. With three weeks and about two participants per weekday, almost 30 should have been tested, which is within the range of values commonly seen in related literature.

Form an organisational point of view, the experiment would still need to be officially approved because it has not been decided yet on which measures for presence to use. This will involve — as stated on the last page of the ethics form in the appendix — preparing appropriate recruitment material, the demographic and presence-related questionnaire, a consent form that informs participants about what data will be retrieved and how it will be stored, a health and safety project plan and an outline of the experiment procedure itself. This could be done in only one week.

As already stated in the ethics form, participants are expected to feel very comfortable in the IVE because it would involve an engaging sequence of tasks. In case the study would be following a between-subjects design, each participant would only have to accomplish the task sequence once, which would make the whole procedure more pleasant for them. Although some of the behavioural measures would be surprising and could scare some of the participants, this is expected to have no significant influence on their well-being during the experiment.

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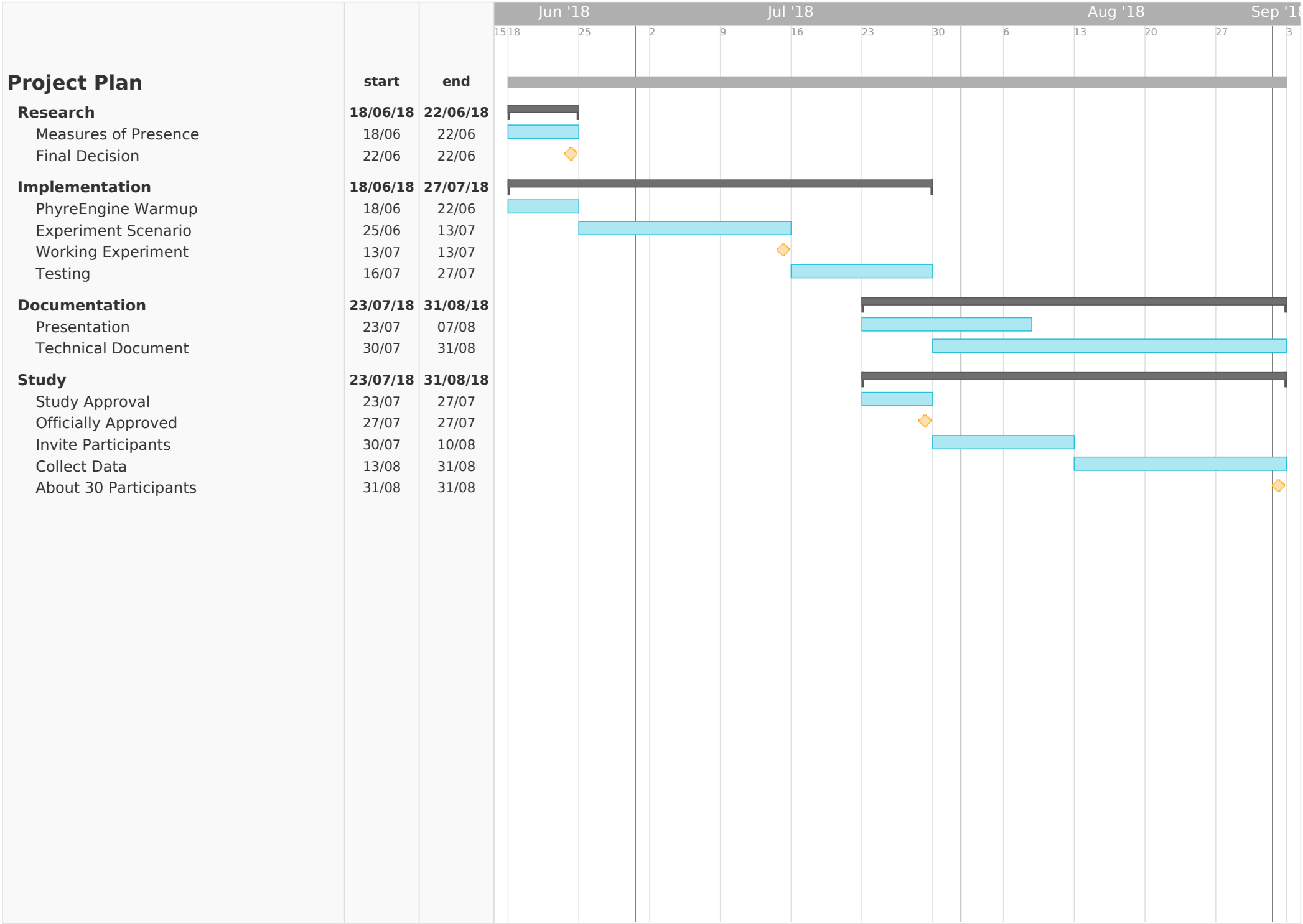

Project Plan	start	end
Research	**18/06/18**	**22/06/18**
Measures of Presence	18/06	22/06
Final Decision	22/06	22/06
Implementation	**18/06/18**	**27/07/18**
PhyreEngine Warmup	18/06	22/06
Experiment Scenario	25/06	13/07
Working Experiment	13/07	13/07
Testing	16/07	27/07
Documentation	**23/07/18**	**31/08/18**
Presentation	23/07	07/08
Technical Document	30/07	31/08
Study	**23/07/18**	**31/08/18**
Study Approval	23/07	27/07
Officially Approved	27/07	27/07
Invite Participants	30/07	10/08
Collect Data	13/08	31/08
About 30 Participants	31/08	31/08

Sheffield Hallam University

RESEARCH ETHICS CHECKLIST FOR STUDENTS (SHUREC7)

This form is designed to help students and their supervisors to complete an ethical scrutiny of proposed research. The SHU Research Ethics Policy should be consulted before completing the form.

Answering the questions below will help you decide whether your proposed research requires ethical review by a Designated Research Ethics Working Group.

The final responsibility for ensuring that ethical research practices are followed rests with the supervisor for student research.

Note that students and staff are responsible for making suitable arrangements for keeping data secure and, if relevant, for keeping the identity of participants anonymous. They are also responsible for following SHU guidelines about data encryption and research data management.

The form also enables the University and Faculty to keep a record confirming that research conducted has been subjected to ethical scrutiny.

For student projects, the form may be completed by the student and the supervisor and/or module leader (as applicable). In all cases, it should be counter-signed by the supervisor and/or module leader, and kept as a record showing that ethical scrutiny has occurred. Students should retain a copy for inclusion in their research projects, and staff should keep a copy in the student file.

Please note if it may be necessary to conduct a health and safety risk assessment for the proposed research. Further information can be obtained from the Faculty Safety Co-ordinator.

General Details

Name of student	Johannes Schirm
SHU email address	Johannes.Schirm@student.shu.ac.uk
Course or qualification (student)	MSc Games Software Development
Name of supervisor	Dr. Jacob Habgood
email address	j.habgood@shu.ac.uk
Title of proposed research	Evaluating locomotion in virtual reality through presence
Proposed start date	18/06/2018
Proposed end date	31/08/2018
Brief outline of research to include, rationale & aims (250-500 words).	Habgood, Moore, Wilson and Alapont (2018) presented an alternative approach to player locomotion in stationary virtual reality setups that aimed to keep the user oriented and increase their presence in comparison to other techniques involving teleportation. However, no differences were found in the reported levels of presence between the tested conditions – the authors concede that this could be due to the

	way presence was measured in their study. Over the last few decades, the research community discussed many objective measures of presence and how these could be combined with subjective measures, providing as many opportunities to improve this locomotion study through a more direct measurement of presence. Further investigating this novel locomotion technique would be beneficial for all developers of immersive virtual environments (IVEs) who are working with stationary setups, which is an important community to contribute to.
Where data is collected from individuals, outline the nature of data, details of anonymisation, storage and disposal procedures if required (250-500 words).	Participants will sign an informed consent form and fill out demographic and post-experience questionnaires. All questionnaires will only carry the participant's number which will not be related to their name. The mapping between a participant's name and number will be stored in an encrypted file, only accessible by the authors. Furthermore, some real-time data about their performance in the virtual reality scenario will be recorded and only saved alongside their anonymous number.

1. Health Related Research Involving the NHS or Social Care / Community Care or the Criminal Justice Service or with research participants unable to provide informed consent

Question	**Yes/No**
1. Does the research involve? • Patients recruited because of their past or present use of the NHS or Social Care • Relatives/carers of patients recruited because of their past or present use of the NHS or Social Care • Access to data, organs or other bodily material of past or present NHS patients • Foetal material and IVF involving NHS patients • The recently dead in NHS premises • Prisoners or others within the criminal justice system recruited for health-related research***** • Police, court officials, prisoners or others within the criminal justice system***** • Participants who are unable to provide informed consent due to their incapacity even if the project is not health related	No
2. Is this a research project as opposed to service evaluation or audit? *For NHS definitions please see the following website* http://www.hra.nhs.uk/documents/2013/09/defining-research.pdf	Yes

If you have answered **YES** to questions **1 & 2** then you **must** seek the appropriate external approvals from the NHS, Social Care or the National Offender Management Service (NOMS) under their independent Research Governance schemes. Further information is provided below.

NHS https://www.myresearchproject.org.uk/Signin.aspx

***** All prison projects also need National Offender Management Service (NOMS) Approval and Governor's Approval and may need Ministry of Justice approval. Further guidance at:

http://www.hra.nhs.uk/research-community/applying-for-approvals/national-offender-management-service-noms/

NB FRECs provide Independent Scientific Review for NHS or SC research and initial scrutiny for ethics applications as required for university sponsorship of the research. Applicants can use the NHS proforma and submit this initially to their FREC.

2. Research with Human Participants

Question	**Yes/No**
Does the research involve human participants? This includes surveys, questionnaires, observing behaviour etc.	Yes
Question	**Yes/No**
1. *Note If YES, then please answer questions 2 to 10* *If NO, please go to Section 3*	OK.
2. Will any of the participants be vulnerable? *Note: Vulnerable' people include children and young people, people with learning disabilities, people who may be limited by age or sickness, etc. See definition on website*	No
3. Are drugs, placebos or other substances (e.g. food substances, vitamins) to be administered to the study participants or will the study involve invasive, intrusive or potentially harmful procedures of any kind?	No
4. Will tissue samples (including blood) be obtained from participants?	No
5. Is pain or more than mild discomfort likely to result from the study?	No
6. Will the study involve prolonged or repetitive testing?	No
7. Is there any reasonable and foreseeable risk of physical or emotional harm to any of the participants? *Note: Harm may be caused by distressing or intrusive interview questions, uncomfortable procedures involving the participant, invasion of privacy, topics relating to highly personal information, topics relating to illegal activity, etc.*	No
8. Will anyone be taking part without giving their informed consent?	No
9. Is it covert research? *Note: 'Covert research' refers to research that is conducted without the knowledge of participants.*	No
10. Will the research output allow identification of any individual who has not given their express consent to be identified?	No

If you answered **YES only** to question **1,** the checklist should be saved and any course procedures for submission followed. If you have answered **YES** to any of the other questions you are **required** to submit a SHUREC8A (or 8B) to the FREC. If you answered **YES** to question **8** and participants cannot provide informed consent due to their incapacity you must obtain the appropriate approvals from the NHS research governance system. Your supervisor will advise.

3. Research in Organisations

Question	**Yes/No**
1. Will the research involve working with/within an organisation (e.g. school, business, charity, museum, government department, international agency, etc.)?	No

2. If you answered YES to question 1, do you have granted access to conduct the research? *If YES, students please show evidence to your supervisor. PI should retain safely.*	
3. If you answered NO to question 2, is it because: A. you have not yet asked B. you have asked and not yet received an answer C. you have asked and been refused access. *Note: You will only be able to start the research when you have been granted access.*	

4. Research with Products and Artefacts

Question	**Yes/No**
1. Will the research involve working with copyrighted documents, films, broadcasts, photographs, artworks, designs, products, programmes, databases, networks, processes, existing datasets or secure data?	Yes
2. If you answered YES to question 1, are the materials you intend to use in the public domain? *Notes: 'In the public domain' does not mean the same thing as 'publicly accessible'.* • *Information which is 'in the public domain' is no longer protected by copyright (i.e. copyright has either expired or been waived) and can be used without permission.* • *Information which is 'publicly accessible' (e.g. TV broadcasts, websites, artworks, newspapers) is available for anyone to consult/view. It is still protected by copyright even if there is no copyright notice. In UK law, copyright protection is automatic and does not require a copyright statement, although it is always good practice to provide one. It is necessary to check the terms and conditions of use to find out exactly how the material may be reused etc.* *If you answered YES to question 1, be aware that you may need to consider other ethics codes. For example, when conducting Internet research, consult the code of the Association of Internet Researchers; for educational research, consult the Code of Ethics of the British Educational Research Association.*	No
3. If you answered NO to question 2, do you have explicit permission to use these materials as data? *If YES, please show evidence to your supervisor.*	Yes, access to the source code of Phyre-Engine and REVEAL has been granted.
4. If you answered NO to question 3, is it because: A. you have not yet asked permission B. you have asked and not yet received and answer C. you have asked and been refused access. *Note You will only be able to start the research when you have been granted permission to use the specified material.*	

Adherence to SHU policy and procedures

Personal statement	
I can confirm that: – I have read the Sheffield Hallam University Research Ethics Policy and Procedures – I agree to abide by its principles.	
Student	
Name: Johannes Schirm	Date:
Signature:	
Supervisor or other person giving ethical sign-off	
I can confirm that completion of this form has not identified the need for ethical approval by the FREC or an NHS, Social Care or other external REC. The research will not commence until any approvals required under Sections 3 & 4 have been received.	
Name: Dr. Jacob Habgood	Date:
Signature:	
Additional Signature if required:	
Name:	Date:
Signature:	

Please ensure the following are included with this form if applicable, tick box to indicate:

	Yes	No	N/A
Research proposal if prepared previously	☒	☐	☐
Any recruitment materials (e.g. posters, letters, etc.)	☐	☒	☐
Participant information sheet	☐	☐	☒
Participant consent form	☐	☐	☒
Details of measures to be used (e.g. questionnaires, etc.)	☐	☐	☒
Outline interview schedule / focus group schedule	☐	☐	☒
Debriefing materials	☐	☐	☒
Health and Safety Project Safety Plan for Procedures	☐	☐	☒