RESEARCH ETHICS BOARDS
APPLICATION FORM

Prospective Research

This form should only be used if new data will be collected. For research involving only secondary use of existing information (such as health records, student records, survey data or biological materials), use the *REB Application Form – Secondary Use of Information for Research.*

This form should be completed using the *Guidance for Submitting an Application for Research Ethics Review*.

SECTION 1. ADMINISTRATIVE INFORMATION [File No: office only]

Indicate the preferred Research Ethics Board to review this research:

[ ] Health Sciences OR [X] Social Sciences and Humanities

Project Title: Haptics and spatial-audio based navigational approach in VR for the visually impaired

1.1 Research team information				
Lead researcher (at Dalhousie)	Name	**AAYUSH SHRESTHA**		
	Email (@dal)	**ashrestha@dal.ca**	Phone	**9023994845**
	Banner #	**B00906766**	Academic Unit	**Faculty of Computer Science**
Co-investigator names, affiliations, and email addresses	Dr. Joseph Malloch, Dalhousie University (jmalloch@dal.ca) Matthew Peachey, Dalhousie University (peacheym@dal.ca)			
Contact person for this submission (if not lead researcher)	Name	N/A		
	Email	N/A	Phone	N/A
Study start date	2024-02-11	Study end date	2024-03-31	

1.2 For student submissions (including medical residents and postdoctoral fellows)			
Degree program	Master's in Computer Science		
Supervisor name and department	Dr. Joseph Malloch (Faculty of Computer Science)		
Supervisor Email (@dal)	jmalloch@dal.ca	Phone	(902) 222-8468

Department/unit ethics review (if applicable). **Undergraduate minimal risk research only**.
Attestation: [N/A] I am responsible for the unit-level research ethics review of this project and it has been approved. Authorizing name: Date:

1.3 Other reviews		
Other ethics review (if any) for this research	Where?	N/A
	Status?	N/A
Scholarly/scientific peer review (if any)	N/A	
Is this a variation on, or extension of, a previously approved Dal REB submission?	[X] No [ ] Yes Dal REB file #_____	
If yes, describe which components of the current submission are the same as the previously approved submission (list section numbers), and which components are different from the previously approved submission (list section numbers). You may also use highlighting to clearly indicate revised text.		

1.4 Funding		[X] Not Applicable
Funding (list on	Agency	**NSERC**
	Award Number	RGPIN-2021-03845

consent form)	Institution where funds are/will be held	[X] Dalhousie University [ ] Other: _____
Was a Dal release of funds agreement issued for this award?		[ ] Yes Date of RoF Agreement: _____

1.5 Attestation(s). The appropriate boxes *must* be checked for the submission to be accepted by the REB

[X] I am the **lead researcher** (at Dalhousie) named in section 1.1. I agree to conduct this research following the principles of the Tri-Council Policy Statement *Ethical Conduct for Research Involving Humans* (TCPS) and consistent with the University *Policy on the Ethical Conduct of Research Involving Humans*.

I have completed the TCPS Course on Research Ethics (CORE) online tutorial.

[X] Yes [ ] No

For Supervisors (of student / learner research projects):

[X] I am the **supervisor** named in section 1.2. I have reviewed this submission, including the scholarly merit of the research, and believe it is sound and appropriate. I take responsibility for ensuring this research is conducted following the principles of the TCPS and University Policy.

I have completed the TCPS Course on Research Ethics (CORE) online tutorial.

[X] Yes [ ] No

SECTION 2. PROJECT DESCRIPTION

2.1 Lay summary

2.1.1 In **plain language**, describe the rationale, purpose, study population and methods to be used. Include a summary of background information or literature to contextualize the study. What new knowledge, or public or scientific benefit is anticipated? [maximum 500 words]

Virtual Reality (VR) is described as a mediated abstraction of reality and touted as a democratizing way to access new worlds and experiences that have always been primarily associated with visual phenomena [8]. However, other sensory feedback mechanisms, such as audio and haptics, that help constitute an equally immersive VR experience have not been thoroughly leveraged. This has led contemporary VR systems to neglect a plethora of users who are in some way visually impaired.

Accessibility in VR for non-sighted users is a usability concern that traditional VR systems have been trying to address in order to establish a more inclusive experience. Moreover, prior studies [2][3] have also been carried out to explore alternatives that exploit haptics and sound to reduce visual dominance in

VR. The caveats are that only a few have incorporated a physical white cane (an essential navigation aid for the non-sighted) in their virtual environment (VE) exploration, and nearly all have restricted the VE to an indoor/confined setting. Our study intends to fill this gap by testing our approach to VE exploration in an outdoor cityscape simulation combined with navigational methodologies that employ a haptics-based white cane prototype and a commercial omnidirectional VR slide-mill (KATVR Walk Mini S) for locomotion.

In order to conduct this study, we will recruit sighted participants within the university community. The reason for recruiting sighted participants is that we want to conduct this user study as a preliminary study to serve as a proof of concept of our approach to test out the overall feasibility, tolerability, and empathetic efficacy. The insights gained from this study will be used to improve the current implementation, and future work will involve testing with actual non-sighted participants.

For the first part of the study, the participants will undergo a training session to navigate a VE effectively using our prototype cane and slide mill. Following this, they will be asked to perform three tasks of different natures and varying cognitive loads to test out our system. However, during this phase, they will not have access to any visual information and will have to rely solely on their sense of hearing and touch. While the participants perform the tasks, we will video record their interactions, screen record their in-game VE exploration performance, and log essential game statistics.

This study aims to build on inclusive approaches to accommodate non-sighted users, not only by promoting accessibility as a means to appropriate VR systems but also by providing sighted users with a medium to experience and understand the perspective of their non-sighted counterparts. Additionally, we expect to share the insights from this study in the form of an academic publication through different international human-computer interaction (HCI) conferences.

[ ] This is a pilot study.

[X] This is a fully developed study.

2.1.2 Phased review. If a phased review is being requested, describe why this is appropriate for this study, and which phase(s) are included for approval in this application. Refer to the guidance document before requesting a phased review.

[X] Not applicable

2.2 Research question

State the research question(s) or research objective(s).

1. [RQ1] What is the level of differentiation between virtual textures that sighted individuals can achieve without visual cues using the system?
2. [RQ2] How effectively can sighted individuals navigate in the VE using only audio cues and haptic feedback through our system without visual information?
3. [RQ3] Does the absence of visual information in VE navigation reduce cognitive load in sighted users, or does their inherent reliance on visual cues increase overall cognitive load?

2.3 Recruitment

2.3.1 Identify the study population. Describe and justify any inclusion / exclusion criteria. Also describe how many participants are needed and how this was determined.

The study population is people who are interested in the idea of exploring VR in a non-conventional way without any visual information. Previous studies in this field have recruited participants who were either visually impaired or sighted. The studies with non-sighted participants [1][2][3] had a sample size of ~7, whereas the ones with sighted participants [6][7] had a sample size of ~39. Since our primary objective for the study is to test our system's performance from a sighted user's perspective, we aim to collect as much quantitative data as possible. Thus, the estimated sample size of this study is 20 sighted participants.

The inclusion criteria for participation include individuals with prior experience or knowledge of VR systems and no history of VR-induced motion sickness. However, participants will not be eligible to participate if they have visual or hearing impairments. This is to ensure the integrity of the collected data and prevent any possible form of bias. Nevertheless, individuals with general visual acuity issues such as myopia and hypermetropia are eligible to participate. Moreover, other exclusion criteria in this study are defined to overcome practical issues related to the opportunity to participate in the study itself, such as:

- Individuals with accessibility needs, such as motor and cognitive disabilities, that cannot be met through the user interface and head-mounted displays (HMDs) used to run the study.
- Individuals who cannot attend the study settings in person.
- Individuals who have a previous neurological illness, heart condition, or any medical condition that significantly restricts full-body mobility, inhibiting them from standing and walking comfortably.

Participants will be made aware of the in-person participation requirement at the designated research facility and all of the inclusion/exclusion criteria in the recruitment notice for this study (Appendix B).

2.3.2 Describe recruitment plans and append recruitment instruments. Describe who will be doing the recruitment and what actions they will take, including any screening procedures.

Recruitment will take place within the Dalhousie Campus in Halifax. We will aim to recruit university community members interested in experiencing a non-conventional approach to VR with no visuals. The recruitment will be conducted by the lead researcher (Aayush Shrestha) during the Winter '24 term. Aayush will be responsible for posting the advertisement online via email, on the notice boards around the Dalhousie campus, and the FCS HCI cluster Teams channel.

Once someone shows interest in participating in the user study, they will be informed of the location of the user study, asked about their experience and familiarity with VR applications, and if they have any limitations that prevent them from participating, such as any visual impairment, susceptibility to VR induced motion sickness, and any medical condition (physiological or psychological) that can significantly restrict full-body mobility. If the answers provided by the participants meet the inclusion criteria, we will send them the consent form and book a time for study. The answers to these questions will not be recorded, and if someone who shows interest is screened out, we will delete all communication with them.

2.3.3 If you require permission, cooperation, or participation from a community, organization or company to recruit your participants, describe the agreement obtained from the relevant group(s). Attach correspondence indicating their cooperation and/or support (required). Describe any other community consent or support needed to conduct this research. (If the research involves Indigenous communities complete section 2.11).

[X] Not applicable

2.4 Informed consent process

2.4.1 Describe the informed consent process:

A) How, when and by whom will the study information be conveyed to prospective participants? How will the researcher ensure prospective participants are fully informed?

For our study, the advertisement outlines all risks associated with the research, as well as the role of the person posting the advertisement. A description of the advertisement for the study is attached to this application.

We will begin by sending an email containing both the recruitment advert and the consent form, including all the necessary study information. If a participant agrees to participate, they will be required to fill out the form in person before starting the study. By reading the consent form, participants who complete the consent process will receive comprehensive information about the study, including any risks and benefits associated with participation. The consent form will provide details such as a description of the study and its purpose, contact information, potential risks and benefits of participation, and the right to withdraw without facing any penalties.

B) Describe how consent will be documented (e.g. written signature, audio-recorded, etc).

Consent will be documented by written signature on a paper consent form.

[X] Append copies of all consent information that will be used (e.g. written consent document, oral consent script, assent document/script, etc).

Note: If the research will involve third party consent (with or without participant assent), and/or ongoing consent, ensure these are described above.

2.4.2 Discuss how participants will be given the opportunity to withdraw their participation (and/or their data) and any time (or content) limitations on this. If participants will not have opportunity to withdraw their participation and/or their data explain why.

Participants have the right to withdraw from voluntary participation at any point before completing the study without incurring any penalties (see also 2.5.3 Compensation).

Participants who withdraw during the study will be excluded from analysis, and their data will be discarded. Once the study is complete, upon receiving a request from participants to remove user-specific data, it will be deleted entirely from all the mediums. This request can only be considered within the first two weeks from the date of the user study, as after that point, the data will have already been used in the analysis phase.

2.4.3 If an alteration/exception to the requirement to seek prior informed consent is sought, address the criteria in TCPS article 3.7A. If the alteration involves deception or nondisclosure, also complete section 2.4.4.

[X] Not applicable

2.4.4 Describe and justify any use of deception or nondisclosure and explain how participants will be debriefed.

[X] Not applicable

2.5 Methods, data collection and analysis

2.5.1

A) Where will the research be conducted?

The research will be conducted at the Blackout Lab in the Human Computer Interaction, Graphics, and Visualization research cluster installations in Dalhousie's Paramount Building, located at 1577 Barrington St., Halifax.

B) What will participants be asked to do?

Our user study utilizes VR hardware other than the conventional HMDs and VR joysticks. This includes a commercial omnidirectional VR slide-mill (KATVR Walk Mini S) for VE locomotion and a white cane prototype modified for haptic vibration rendering. The methodology for participants to experience the VE is also non-conventional since there will be no visual display, and information is conveyed only in the form of audio and vibrotactile feedback. Due to the novelty of the apparatus, for the first phase of the user study – the training phase, we will conduct two sessions dedicated to acquainting the participants with how to use the slide mill and the cane prototype. To start the training phase, participants will be helped to safely step on to the slide mill and will be buckled in while ensuring unobstructed 360-degree movement. They will then put on the HMD and be asked to hold the cane prototype in their dominant hand. They will then learn to navigate a cityscape simulation game using the apparatus provided; for this phase, they will have access to visuals, audio, and haptics. The lead researcher will instruct participants on how to get used to the apparatus and what feedback to expect.

For the second phase of the user study – the testing phase, the participant will continue to be on the slide mill along with the HMD and the cane prototype. They will be asked to perform three different tasks, namely surface recognition (T1), road crossing (T2), and scavenger hunt (T3). At the start of every task, the lead researcher will explain the specifics of the task and what they are expected to do in order to complete it. All these three tasks have different levels and/or versions with increasing levels of complexity (Table 1). They are intended to test out the usability of our VE exploration approach, collect performance data, and assess behavioral cognitive load [10]. The first task – T1, tests the cane prototype's ability to render haptic profiles of virtual surfaces with and without corresponding interaction sound. The participants will have to complete three variations of T1 with no visual feedback. The second task – T2, tests the spatial audio beacons within the VE. The participants will have to complete two versions of this task, each with the same two levels. The first version of this task will be with visuals, followed by the one without any visuals. Finally, the third task -T3, tests the combination of the slide mill, the cane, and the spatial audio cues for complex navigation in the VE. Similar to T2, in this task, the participants will have to complete two versions of the task (with and without visuals), each with the same two levels. In order to mitigate the possibility of the learning effect bias, we plan to reverse the order of execution of each

version of T1 and T2 for every participant. There will be a mandatory 5-minute break between T1 and T2, followed by a voluntary 5-minute break between T2 and T3.

Once the testing phase is complete, they will be assisted in safely stepping down from the slide mill. They will sit at a table to share their demographic data and experience through four written post-study questionnaires *(Appendix D)* and a verbal semi-structured interview. Once the feedback session is completed, this will mark the end of a successful user study, and the participants will be compensated CAD 20 in thanks for their time. They will then be escorted out of the research premises.

Table 1: Breakdown of the three primary tasks for the testing phase

Task	**Category/Version**	**Levels/Variation**	**Complexity**	**Task completion time (mins)**
[T1] Surface Recognition	NV*	T1.1	Low	10
		T1.2		
		T2.3		
[T2] Road Crossing	NV	T2.1	Medium	15
		T2.2		
	WV**	T2.1		
		T2.2		
[T3] Scavenger hunt	NV	T3.1	High	25
		T3.2		
	WV	T3.1		
		T3.2		

C) What data will be collected using what research instruments? *(Note that privacy and confidentiality of data will be covered in section 2.6)*

As discussed in 2.5.1 B, the user study has two phases – testing and training. For the testing phase, no data will be collected in any form. However, for the training phase, for each task (T1, T2, and T3), the following instruments will be used to collect data:

- The participant's interaction with the apparatus will be video recorded.
- The VE exploration performance and navigation patterns will be recorded through the virtual camera in the VE.
- Two-dimensional position data of the participant in the VE will be collected using the HMD and cane's acceleration data through an accelerometer sensor
- Logged game data will record specific performance metrics such as the number of interactions with virtual objects, time to complete a task, and time to reach a target.
- There will be four online questionnaires altogether. Two of the questionnaires will collect demographic and self-reported usability data (*Appendix D - Demographic and System Usability*

** No Visuals ** With Visuals*

Scale). The other two would be NASA-TLX [9] based questionnaires (*Appendix D – Work Load Assessment*). NASA-TLX has consistently been used in prior research [1][2][4][10] as well for recording the overall subjective cognitive load. We will use it to collect experiential cognitive load while performing tasks with and without visual cues, along with the system's overall usability through the System Usability Scale (SUS) questionnaire.

- The semi-structured interview session will be audio recorded, and the participant's overall experience and feedback will be conveyed verbally.

D) How much of the participant's time will participation in the study require?

The entire user study will require approximately 90 minutes (see Table 1) of the participant's time. The training session consists of two rounds and will last for 20 minutes. The testing session has three rounds, with three tasks in each round, taking a total of 50 minutes. Finally, the user study concludes with a post-study survey and a semi-formal interview, which requires 20 minutes to complete.

[X] Append copies of all research instruments (questionnaires, focus group questions, standardized measures, etc)

~~[N/A] This is a clinical trial (physical or mental health intervention) – ensure section 2.12 is completed~~

2.5.2 Briefly describe the data analysis plan. Indicate how the proposed data analyses address the study's primary objectives or research questions.

For our first research goal (RQ1), we will analyze experimental data collected from video and game-play screen recordings for T1. We will treat the haptic vibrations from the cane and the cane interaction sound in the game as two categorical independent variables influencing the virtual surface identification success rate (continuous dependent variable). We will then perform a two-way Analysis of Variance (ANOVA) to analyze the combined and standalone influence of the independent variables on the success rate of T1.

For our second research goal (RQ2), we will perform a quantitative analysis of logged game data collected from T2 and T3, along with ratings from the SUS survey (*Appendix D*). Moreover, we plan to analyze the qualitative data from the interviews and task performance video recordings by performing a thematic analysis. The quantitative analysis will help to visualize the performance of the participants using metrics such as the time to complete a task or sub-task successfully, the error rate in navigational choices such as direction, target selection, and vehicular collision, and the overall usability of the system by normalizing the SUS score to produce a percentile ranking. For the thematic analysis, the interview audio recordings will be coded, and ex-situ observation will be noted by analyzing the task performance video recordings. The qualitative data will then be used to generate initial codes and establish general patterns to identify and develop themes. This technique will provide a top-down approach to parse dense subjective data to a more generic themes-based finding.

For our third research goal (RQ3), we will analyze the normal distribution of the NASA-TLX ratings for the two versions of the tasks (with and without visuals) using the Shapiro-Wilk test. Depending on its results, either a Student's T-Test or a Wilcoxon's signed-rank [1] test will be applied. To further assess the data, we will use box plots to visualize the parametric ratings of the NASA TLX dimensions.

2.5.3 Describe any compensation that will be given to participants and how this will be handled for participants who do not complete the study. Discuss any expenses participants are likely to incur and whether/how these will be reimbursed.

Participants will receive a compensation of CAD 20 after successfully completing the user study and before leaving the lab. If a participant withdraws from the study in between the sessions, they will receive a pro-rated compensation based on the amount of time invested as specified below. The payment will be made in cash to ensure anonymity is respected.

Participation level	**Study hours invested (minutes)**	**Compensation Amount (CA$)**
Baseline participation	0-44	10
Partial participation	45-59	15
Completed user study	60-90	20

The HCI research cluster has all the equipment needed to run this user study, so participants don't need to bear any expense from their end.

2.6 Privacy and confidentiality

2.6.1

A) Describe who will have knowledge of participants' identities.

The researcher running the user study (Aayush Shrestha) will know the participants' identities as they will be with them in person during the user study. This researcher won't have any influence or authority over the participants, e.g., by their teacher or supervisor. This researcher is responsible for storing, directly and indirectly, identifying information from the consent form and demographic survey. The demographic survey and the data collected from the user study won't be linked to the consent form to prevent the re-linking of both information. This includes providing a random identifier to each participant.

B) Describe the level of identifiability of the study data (anonymous, anonymized, de-identified/coded, identifying) (see TCPS Chapter 5A – types of information for definitions).

Given the presence of video recordings in this study, it is essential to acknowledge that the data may not be considered entirely "anonymized". Therefore, we will take the following measures to maintain the level of identifiability of the study data as "de-identified/coded":

1. Blurring identifying features: We will apply techniques to blur or mask any identifying features present in the video recordings.
2. Participant code assignment: Instead of using participants' real names, we will assign unique codes or identifiers to each participant. These codes will be used to reference individuals in the recordings and will not be kept, allowing future re-linkage.
3. Restricted access: The video recordings will be limited to the researchers involved in the study. Strict regulations will be implemented to control and monitor access to the data.
4. Secure storage: After each user study session, the video recording from the camera's SD card is transferred, de-identified, and uploaded to a private folder hosted on Dalhousie University's institutional cloud storage platform - Microsoft SharePoint. This ensures that the camera's SD card doesn't contain any participant information whatsoever. The lead researcher will maintain this SharePoint folder, and access to it will be restricted to only members of the research team. The

access is maintained by providing explicit permission to access, view, and edit data within the folder. Moreover, since it will be on institutional SharePoint, even members of the research team with permission to access it will require authorized credentials to sign in, which provides an added layer of security.

It is important to note that participants will be clearly informed about the use of video recordings, and their informed consent will be obtained before any recording takes place. Additionally, we will provide a detailed explanation of how the recordings will be handled, de-identified, and stored to ensure transparency and maintain the privacy and confidentiality of participants.

C) Specify which members of the research team (or others) will have access to participants' data and for what purpose.

The primary investigator, Aayush Shrestha, his supervisor, Dr. Joseph Malloch, and Matthew Peachey, will have access to the data for analysis and feedback. Any co-investigator who may join after the study or in due course of the project will be given access to the data only after an REB amendment. However, de-identified, aggregate data might be shared with other lab personnel as internal presentations and data analysis sessions.

D) Describe measures to ensure privacy and confidentiality of study documents and participant data during the data collection and analysis phase. *[Note that plans for long term storage will be covered in 2.6.2*]

- Address: handling of documents/data during data collection; transportation or transfer of documents/data; storage of documents/data (during the study).
- If a key-code will be maintained, describe how it will be kept secure.
- For electronic data, describe electronic data security measures, including file encryption and/or password protection as applicable.
- For hard copy documents, describe physical security measures (specify location).

Data collected in this study will be collected and stored for a limited time in a private SharePoint folder on the Dalhousie University institutional cloud storage platform. All data stored in SharePoint, similar to OneDrive, has multiple layers of security (BitLocker disk-level encryption and per-file encryption) and is stored on institutional servers. Access to the SharePoint folder will be managed by the lead researcher at both the level of the folder and the files within. Moreover, even after permission is granted to members of the research team, the login is governed by institutional credentials that provide an added level of security. A key code will be maintained throughout the study that will be stored separately from any de-identified data inside a locked file cabinet in the lead researcher's office space, which has restricted access.

Storing the data on SharePoint will serve as a centralized and secure platform for the research team to access and modify the data. This approach eliminates the need for physical data transfer between team members through any online or offline medium. Additionally, following each user study session, the paper consent forms are stored separately from any de-identified data inside a locked file cabinet in the lead researcher's office space, which has restricted access.

[N/A] This research involves personal health records (ensure section 2.13 is completed)

2.6.2 Describe plans for data retention and long-term storage (i.e. how long data will be retained, in what form and where). Will the data eventually be destroyed or irreversibly anonymized? If so, what procedures will be used for this? Discuss any plans for future use of the data or materials beyond the study currently being reviewed.

The 3-2-1 backup rule will be followed for data storage and backup. Team members will transfer the anonymous and anonymized data stored in Dalhousie University's institutional SharePoint list, secure cloud-based storage developed by Microsoft, and onto two encrypted external storage hard drives. SharePoint can be easily accessed and limited to the researchers leading the consent and data collection efforts. One of the external storage hard drives will be stored offsite, and another will be kept in a locked filing cabinet within the lead researcher's office. The data will be stored for a maximum of 2 years, after which it will be eventually destroyed from all mediums.

[ ] This research will be deposited in a data repository (ensure section 2.14 is completed)

2.6.3

Describe if/how participant confidentiality will be protected when research results are reported:

A) For quantitative results - In what form will study data be disseminated?

[X] Only aggregate data will be presented

[ ] Individual de-identified, anonymized or anonymous data will be presented

[ ] Other. If "other", briefly describe dissemination plans with regard to identifiability of data.

[ ] Not applicable, only qualitative data will be presented

B) For qualitative results - Will identifiable data be used in research presentations/publications? If participants will be quoted, address consent for this and indicate whether quotes will be identifiable or attributed.

The qualitative results will contain de-identified quotes to support and contextualize quantitative results. The consent for this will be addressed as part of the signed paper consent form (*Appendix C*).

[] Not applicable, only quantitative data will be presented

2.6.4 Address any limits on confidentiality, such as a legal duty to report abuse or neglect of a child or adult in need of protection, and how these will be handled. Ensure these are clear in the consent documents. (See the guidance document for more information on legal duties and professional codes of ethics).

[X] Not applicable

2.6.5 Will any information that may reasonably be expected to identify an individual (alone or in combination with other available information) be accessible outside Canada? And/or, will you be using any electronic tool (e.g. survey company, software, data repository) to help you collect, manage, store, share, or analyze personally identifiable data that makes the data accessible from outside Canada?

[X] No

[ ] Yes. If yes, refer to the University *Policy for the Protection of Personal Information from Access Outside Canada*, and describe how you comply with the policy (such as securing participant consent and/or securing approval from the Vice President Research and Innovation).

2.7 Risk and benefit analysis

2.7.1 Discuss what risks or discomforts are anticipated for participants, how likely risks are and how risks will be mitigated. Address any particular ethical vulnerability of your study population. Risks to privacy from use of identifying information should be addressed. If applicable, address third party or community risk. (If the research involves Indigenous communities also complete section 2.11)

We do not foresee any major risks for the participants; however, we have carefully considered potential risks that the participants might be exposed to due to the novelty of our experiment and the inherent nature of VR experiences. Thus, it is only prudent to be ready for any risks and discomfort.

- There is a small risk of physical or mental fatigue brought about by the tasks to be performed as they require whole-body movement. To mitigate this risk, we have scheduled a compulsory break between T1 (after completing the training) and T2, followed by a voluntary break before the start of the final task. Both of the breaks will be for ~ 5 minutes, where the participants will be allowed to rest in a comfortable seated position. Participants will also be informed that they are free to take additional breaks whenever they choose.
- We plan to use an omnidirectional slide mill (KATVR Walk Mini S) to enable participants to physically navigate through the VE. The sensor plate on which participants stand provides a slippery surface when wearing special shoe covers, and movement in the VE is controlled by sliding the feet on the sensor plate. While using the slide mill participants will be securely buckled into a waist strap and thigh straps, making it impossible to trip, overbalance, or fall down. There is a small risk while mounting or dismounting from the platform since the participant will not be buckled – this risk will be mitigated by a) insisting that all mounting/dismounting be performed with assistance from the study personnel, b) providing a portable handrail for support, c) ensuring that the rotating back support of the slide mill is always locked (preventing rotation) except when the safety straps are fastened.
- Other VR studies include risks of losing balance, crashing into surrounding real-life objects, and feelings of nausea brought about by latency-induced conflict between visual and vestibular senses. This study does not suffer from these risks, since participants will be securely fastened into the slide mill during the study and we will make use of modern low-latency VR headsets. For some of our conditions no visual information will be provided at all so no visual-vestibular conflict is possible. Out of an abundance of caution, our screening process excludes any participant with a history of

VR-induced motion sickness as well. However, for any anomalies, the lead researcher will make sure that the users take breaks or cease participation at any time without penalty.

- There is a small risk of boredom or frustration that may be experienced during the study. This risk is mitigated by ensuring that participants are aware of their right to take breaks and/or withdraw from the study.
- There is a small risk that participants might experience anxiety or claustrophobia due to the absence of visual stimuli; however, we believe most participants will find the study environment and tasks interesting and enjoyable. This risk is mitigated by ensuring that participants are assured that study personnel will be present in the room at all times and that participants are aware of their right to take breaks and/or withdraw from the study.
- There is a small risk of loss of confidentiality if a data breach occurs. To mitigate this risk, investigators will not record identifying personal information (such as names and emails) with the study data. For the lab experiment, we will run the experiment in a closed lab, where only the researcher running the user study and the participant will be present; this will prevent other people from identifying participants' identities. We will also leave time between participants to help them enter/exit the lab without seeing other participants. Please note that none of the data recorded for this study are "sensitive" or potentially damaging to a participant's reputation, employment, etc.

2.7.2 Identify any direct benefits of participation to participants (other than compensation), and any indirect benefits of the study (e.g. contribution to new knowledge).

Apart from being able to understand and experience a non-conventional approach to VR navigation, the direct benefit of participation in this study is the increased empathetic literacy of the participants toward the people who suffer from visual impairments. After this experiment, they will better understand the day-to-day navigational perils of people with visual impairments and foster greater empathy and awareness, leading to a more thoughtful and inclusive outlook [5].

The indirect benefit is that their participation will assist us in getting a deeper insight into design flaws, usability issues, or accessibility challenges of our system that could help refine our implementation in order to carry out a separate future study with non-sighted participants. Moreover, the immediate implication is that this study can augment existing knowledge in this field, which can carry over to create accessible VR systems that will not only be inclusive but also be used as an assistive training aid.

2.8 Provision of results to participants and dissemination plans.

2.8.1 The TCPS encourages researchers to share study results with participants in appropriate formats. Describe your plans to share study results with participants and discuss the process and format.

The primary investigator will rely on a project website to disseminate all findings obtained in this study, including research articles, slide presentations, and videos. At the end of the recruitment, online survey, or user study, participants will be thanked for their participation and will be provided with a link to the website so that they may learn more about the research.

2.8.2 If applicable, describe how participants will be informed of any material incidental findings – a discovery about a participant made in the course of research (screening or data collection) that is outside the objectives of the study, that has implications for participant welfare (health, psychological or social). See TCPS Article 3.4 for more information.

[X] Not applicable

2.8.3 Describe plans for dissemination of the research findings (e.g. conference presentations, journal articles, public lectures etc.).

The findings obtained from this research will be disseminated through conference presentations at both local (i.e., CHCCS/SCDHM Graphics Interface) and international venues (e.g., ACM CHI).

2.9 Research Team

2.9.1 Describe the role and duties of all research team members (including students, RA's and supervisors) in relation to the overall study.

- Aayush Shrestha: Master's in computer science student at Dalhousie University. He is the lead researcher responsible for the user study design, recruitment and screening of participants, running the study, data collection and analysis, and result publication.
- Dr. Joseph Malloch: The supervisor of the primary investigator, responsible for guiding the entire user study and leading the data analysis.
- Matthew Peachey: Ph.D. in computer science student at Dalhousie University. May assist in running the user study and post-study data analysis.

2.9.2 Briefly identify any previous experience or special qualifications represented on the team relevant to the proposed study (e.g. professional or clinical expertise, research methods, experience with the study population, statistics expertise, etc.).

- Aayush Shrestha:
  He has experience with assistive technologies, designing and conducting user studies in a controlled lab environment, and exposure to qualitative and quantitative data analysis techniques.

- Dr. Joseph Malloch:
  He has experience with assistive technologies for visually impaired users through Digital Musical Instruments (DMIs) for performing arts. He has prior experience supervising and conducting studies in the AR/VR paradigm along with statistical data analysis techniques for HCI-based experiments.

- Matthew Peachey:
  He has prior experience in conducting HCI user studies along with knowledge in gathering and analyzing data.

2.10 Conflict of interest

Describe whether any dual role or conflict of interest exists for any member of the research team in relation to potential study participants (e.g. TA, fellow student, teaching or clinical relationship), and/or study sponsors, and how this will be handled.

[X] Not applicable

2.11 Research involving Indigenous peoples

Consult TCPS Articles 9.1 and 9.2 in determining whether this section is applicable to your research.

[X] Not applicable – go to 2.12

~~2.11.1 If the proposed research is expected to involve people who are Indigenous, describe the plan for community engagement (per TCPS Articles 9.1 and 9.2). If community engagement is not sought, explain why the research does not require it, referencing TCPS article 9.2.~~

~~2.11.2 State whether ethical approval has been or will be sought from Mi'kmaw Ethics Watch and if not, why the research does not fall under their purview. If the research falls under the purview of other Indigenous ethics groups, state whether ethical approval has been or will be sought.~~

~~2.11.3 Describe plans for returning results to the community and any intellectual property rights agreements negotiated with the community with regard to data ownership (see also 2.11.4 if applicable). Append finalized versions of applicable research agreements.~~

~~2.11.4 Does this research incorporate OCAP (Ownership, Control, Access, and Possession) principles described in TCPS Article 9.8?~~

~~[ ] Yes. Explain how.~~

~~[ ] No. Explain why not.~~

2.12 Clinical trials

[X] Not applicable – go to 2.13

2.12.1 Will the proposed clinical trial be registered?

[ ] No. Explain why not.

[ ] Yes. Indicate where it was/will be registered and provide the registration number.

2.12.2 If a novel intervention or treatment is being examined, describe standard treatment or intervention, to indicate a situation of clinical equipoise exists (TCPS Chapter 11). If placebo is used with a control group rather than standard treatment, please justify.

2.12.3 Clearly identify the known effects of any product or device under investigation, approved uses, safety information and possible contraindications. Indicate how the proposed study use differs from approved uses.

[ ] Not applicable

2.12.4 Discuss any plans for blinding/randomization.

2.12.5 What plans are in place for safety monitoring and reporting of new information to participants, the REB, other team members, sponsors, and the clinical trial registry (refer to TCPS Articles 11.6, 11.7, 11.8)? These should address plans for removing participants for safety reasons, and early stopping/unblinding/amendment of the trial. What risks may arise for participants through early trial closure, and how will these be addressed? Are there any options for continued access to interventions shown to be beneficial?

2.13 Use of personal health information

[X] Not applicable

2.13.1 Research using health information may be subject to Nova Scotia's *Personal Health Information Act*. Describe the personal health information (definition explained in the guidance document) required and the information sources, and explain why the research cannot reasonably be accomplished without the use of that information. Describe how the personal health information will be used, and in the most de-identified form possible.

~~2.13.2 Will there be any linking of separate health data sets as part of this research?~~

~~[ ] No~~

~~[ ] Yes~~

~~If yes:~~

~~A) Why is the linkage necessary?~~

~~B) Describe how the linkage will be conducted (it is helpful to append a flow diagram)~~

~~C) Does that linkage increase the identifiability of the participants?~~

~~2.13.3 Describe reasonably foreseeable risks to privacy due to the use of personal health information and how these will be mitigated.~~

2.14 Data Repositories

[X] Not applicable

~~2.14.1 Identify and describe the data repository in which the research data will be deposited. What is its focus, who are its target users, who can access deposited data and under what circumstances? For how long will the data be kept in the repository?~~

~~2.14.2 Describe the data set to be released to the repository. If there is personal and/or sensitive information in the data, describe how you will prepare the data for submission to the repository and mitigate risks to privacy. Identify all fields that will be included in the final data set (include as an appendix).~~

~~2.14.3 Is agreeing to have one's data deposited a requirement for participation in the study? If yes, provide a justification. If no, indicate how participants can opt in or out.~~

SECTION 3. APPENDICES

Appendices Checklist

[X] Reference list

[N/A] Permission or support/cooperation letters (e.g. School Board, care facility, anyone whose cooperation or permission you need to recruit participants or conduct research)

[N/A] Research agreements (required for research involving Indigenous communities)

[X] Recruitment documents (posters, oral scripts, online postings, invitations to participate, etc.)

[N/A] Screening documents

[X] Consent/assent documents or scripts

[X] Research instruments (questionnaires, interview or focus group questions, etc.)

[N/A] Debriefing and/or study results templates

[N/A] List of data fields included in data repository

[N/A] Confidentiality agreements

APPENDIX A – REFERENCE LIST

[1] Julian Kreimeier, Pascal Karg, and Timo Götzelmann. 2020. BlindWalkVR: formative insights into blind and visually impaired people's VR locomotion using commercially available approaches. In Proceedings of the 13th ACM International Conference on PErvasive Technologies Related to Assistive Environments (PETRA '20). Association for Computing Machinery, New York, NY, USA, Article 29, 1–8. https://doi.org/10.1145/3389189.3389193

[2] Julian Kreimeier and Timo Götzelmann. 2019. First Steps Towards Walk-In-Place Locomotion and Haptic Feedback in Virtual Reality for Visually Impaired. In Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems (CHI EA '19). Association for Computing Machinery, New York, NY, USA, Paper LBW2214, 1–6. https://doi.org/10.1145/3290607.3312944

[3] Alexa F. Siu, Mike Sinclair, Robert Kovacs, Eyal Ofek, Christian Holz, and Edward Cutrell. 2020. Virtual Reality Without Vision: A Haptic and Auditory White Cane to Navigate Complex Virtual Worlds. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20). Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3313831.3376353

[4] J. A. Bueno-Vesga, X. Xu and H. He, "The Effects of Cognitive Load on Engagement in a Virtual Reality Learning Environment," 2021 IEEE Virtual Reality and 3D User Interfaces (VR), Lisboa, Portugal, 2021, pp. 645-652, doi: 10.1109/VR50410.2021.00090.

[5] Chowdhury TI, Ferdous SMS, Quarles J. VR Disability Simulation Reduces Implicit Bias Towards Persons With Disabilities. IEEE Trans Vis Comput Graph. 2021 Jun;27(6):3079-3090. doi: 10.1109/TVCG.2019.2958332. Epub 2021 May 12. PMID: 31825867.

[6] Krösl, Katharina & Bauer, Dominik & Schwärzler, Michael & Fuchs, Henry & Suter, Georg & Wimmer, Michael. (2018). A VR-based user study on the effects of vision impairments on recognition distances of escape-route signs in buildings. The Visual Computer. 34. 10.1007/s00371-018-1517-7.

[7] Ricci FS, Boldini A, Ma X, Beheshti M, Geruschat DR, Seiple WH, Rizzo JR, Porfiri M. Virtual reality as a means to explore assistive technologies for the visually impaired. PLOS Digit Health. 2023 Jun 20;2(6):e0000275. doi: 10.1371/journal.pdig.0000275. PMID: 37339135; PMCID: PMC10281573.

[8] Ackerman, E. 2021. Virtual Reality Has an Accessibility Problem. Scientific American Voices (Sep. 2021). https://blogs.scientificamerican.com/voices/virtual-reality-has-an-accessibility-problem/

[9] Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), *Human mental workload* (pp. 139–183). North-Holland. https://doi.org/10.1016/S0166-4115(08)62386-9

[10] Armougum, Allan & Orriols, Eric & Gaston-Bellegarde, Alexandre & Joie-La Marle, Chantal & Piolino, Pascale. (2019). Virtual reality: A new method to investigate cognitive load during navigation. Journal of Environmental Psychology. 65. 101338. 10.1016/j.jenvp.2019.101338.

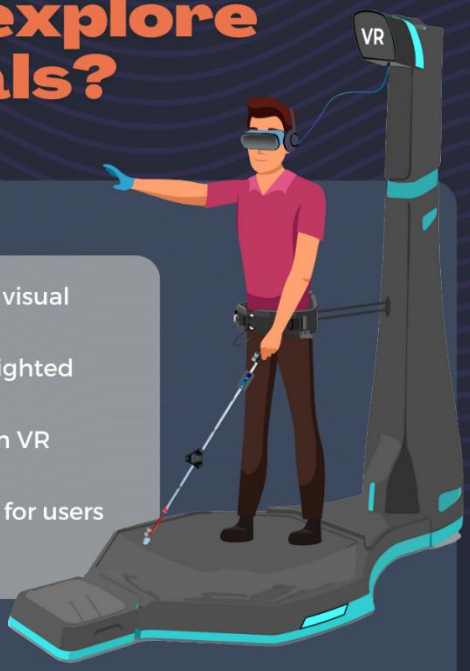
APPENDIX B – RECRUITMENT DOCUMENTS

DAL REB #xxxx

Study venue: GEM Lab, 1577 Barrington St.

Do you want to explore VR with no visuals?

Participants will receive a compensation of $20



What are we researching?

1. Exploring the possibility of using VR without visual feedback
2. Studying the usability of our system from a sighted person's perspective
3. Assessing the relationship of cognitive load in VR experiences with no visuals
4. Trying to gain insights to improve our system for users with actual visual impairments

What will you be asked to do?

1. Train on our system - 20 mins
2. Perform three tasks in VR using the system - 50 mins
3. Fill in post-study questionnaires - 5 mins
4. Share your feedback about the study in an interview - 15 mins

Requirements

1. Any previous experience with Virtual Reality (VR) applications
2. No prior history of VR-induced motion sickness
3. Shouldn't possess any visual or hearing impairments
4. Should be present in person at the HCI lab on the specified date
5. Individuals shouldn't have any medical condition that restricts full-body mobility
6. Individuals whose accessibility needs (if any) can only be met through Head Mounted Displays (HMDs)

To learn more, you can contact the lead researcher:
Aayush Shrestha, Masters student, Faculty of Computer Science
Email: ashrestha@dal.ca, Phone: 902-399-4845

DALHOUSIE UNIVERSITY

APPENDIX C – CONSENT FORM

Project title: Haptics and spatial-audio based navigational approach in VR for the visually impaired

Lead researcher: Aayush Shrestha, Master's student, ashrestha@dal.ca, Faculty of Computer Science, Dalhousie University. *Phone: (902) 399-4845*

Other researchers

Dr. Joseph Malloch (Supervisor) (jmalloch@dal.ca)

Matthew Peachey (peacheym@dal.ca)

Funding provided by: NSERC RGPIN-2021-03845

Introduction

We invite you to participate in a research study conducted by Aayush Shrestha, a Master's student at the Faculty of Computer Science, Dalhousie University. Your decision to take part in this research is entirely voluntary. The information provided below outlines the details of the study, including your involvement, potential benefits, risks, inconveniences, and any discomfort you may experience. If you have any inquiries or concerns, please discuss them with Aayush Shrestha. You are encouraged to ask as many questions as you need to make an informed decision. If you have any questions later on, please contact him at ashrestha@dal.ca.

Purpose and Outline of the Research Study

The main goal of this study is to explore how good sighted individuals can become in navigating a virtual reality-based environment (VE) using only audio and haptic feedback, without relying on any visual information. Additionally, we aim to test whether the absence of visual information increases mental effort, or if reliance on visuals increases the mental load during VE navigation. Insights gained from this investigation will help to make changes to our current approach. This will form a basis for the future version of the system to be tested out with actual participants who are non-sighted or visually impaired. The purpose of this research and futures researches based on this one is to explore the possibility of developing ways to make virtual reality accessible to people who are not able to use it due to some form of vision related disability.

The study comprises two parts: training and testing. During the training phase, participants will get to know about how the system functions and what they can expect in the form of feedback. Later on, in the testing phase, participants will engage in three main tasks using the system, with increasing levels of mental demand. Each task will have certain repetitions, and alternating tasks will increase in the level of complexity. The study will end with a couple of online surveys to collect data about the experience with the system and an interview session to gather feedback on what can be improved upon.

The study will require a maximum of 90 minutes to complete, which includes the time spent on the survey, interview, breaks, reading of the consent form, and completing the study. Participants will be compensated with CA$ 20. The payment will be given to the participants before they leave the lab upon completion of the study. In case of a withdrawal from the study in-between sessions, they will receive a pro-rated compensation based on the amount of time or study phases completed (*specified under "Compensation/Benefits"*).

Who Can Take Part in the Research Study?

Prospective participants with familiarity or understanding of Virtual Reality (VR) and no prior experience of VR-induced motion sickness are eligible to participate in this study. However, participants will not be eligible to participate if they have visual or hearing impairments. Nevertheless, individuals with general visual acuity issues such as myopia and hypermetropia are eligible to participate. Moreover, other exclusion criteria in this study are

defined to overcome practical issues related to the opportunity to participate in the study itself, such as:

- Individuals with accessibility needs, such as motor and cognitive disabilities, that cannot be met through the user interface and head-mounted displays (HMDs) used to run the study.
- Individuals who cannot attend the study settings in person.
- Individuals who have a previous neurological illness, heart condition, or any medical condition that significantly restricts full-body mobility inhibiting them from standing and walking comfortably.

What You Will Be Asked to Do

If you decide to participate in this research, you must visit the lab on a specific date and time to participate in the user study. Firstly, you will be given a consent form to read and sign, following which, the study will start. The study will take a maximum of 90 minutes, divided into three parts - 20 minutes of training, 50 minutes of testing, and 20 minutes of post-study questionnaire and interview. If you continue the experiment,

Our VE has two facets not commonly found in commercial VR experiences, apart from head-mounted displays (HMDs) and VR joysticks. These are - a VR slide mill for in-game locomotion and a novel white cane prototype for virtual surface differentiation through haptic feedback. To familiarize you with these components, you will receive training on using them in the training phase.

During the testing phase, you will be required to use both devices to complete three tasks of different natures and varying cognitive loads. However, during this phase, you will not have access to any visual information and will have to rely solely on your sense of hearing and touch. While you perform these tasks, we will video record your interactions, screen record your in-game VE exploration performance, and log essential game statistics. This data will help us analyze our system's usability from a sighted user's perspective and identify any implementation shortcomings that may form the basis for refined future studies involving non-sighted participants.

Once you have completed the experiment, you will be asked to provide feedback about your overall experience through a survey and an interview. Your input and insights will be valuable in helping us understand the effectiveness of the study and identifying any areas that need improvement.

Possible Benefits, Risks and Discomforts

Most commercially available VR experiences prioritize visual feedback over other senses such as touch and sound, making contemporary VR systems highly visually dominant. This has been found to exclude users who are in some way visually impaired. Your participation in this study helps us assess the usability of our system. Moreover, it helps to better understand the possibility of a VR system that can substitute visual dependency with other sensory modalities to create an equally immersive and inclusive VR experience. On a personal level, your participation may benefit you by helping you attain a level of empathetic literacy toward understanding how people with visual impairments navigate in real-life scenarios.

The risks associated with this study are minimal; there are no known physical or psychological risks for participating in this research. However, participants may experience boredom, exertion, frustration, or fatigue during the study, which is common in these studies requiring full-body interactions. Additionally, participants may feel less confident due to perceived performance. To mitigate these risks, participants are encouraged to take breaks and complete the study at their own pace.

Compensation / Reimbursement

In thanks for participating in our study you will receive a compensation of CA$ 20. The payment will be provided to you before you leave the lab. In case of a withdrawal from the study in-between sessions, they will receive a pro-rated compensation based on the amount of time or study phases completed specified as follows:

Participation level	Study hours invested (minutes)	Compensation Amount (CA$)
Baseline participation	0-44	10
Partial participation	45-59	15
Completed user study	60-90	20

How your information will be protected:
During the testing phase, your interactions will be recorded on video and your in-game performance will be logged as part of the study. However, we are committed to ensuring your anonymity so that all recordings will be de-identified.

We understand the importance of keeping your information confidential and secure. Only the research team will have access to identifying information, and any data that could reveal your identity will be removed before sharing it with anyone outside the team. All team members are required to maintain confidentiality.

All the digital data collected in this user study (logged game data, screen recordings, video/audio recordings, online questionnaires and demographic surveys) will be initially stored in an access-restricted private folder on Dalhousie University's institutional SharePoint. Any physical data (signed consent forms) will be stored separately from any de-identified data inside a locked file cabinet in the lead researcher's office space which has restricted access. Later on, to back up the digitally stored user study data, all the SharePoint folder contents will be backed up onto two separate encrypted external hard drives, one kept in a locked filing cabinet within the researcher's office and another stored offsite.

Your identity will remain confidential, and individual results will not be disclosed in any reports or publications. However, de-identified quotes might be used as part of data analysis to support and contextualize quantitative findings. After the study, identifying information will be deleted from everywhere within two years.

If You Decide to Stop Participating
If you decide to withdraw participation during the user study, you can inform the researcher conducting the user study at any point. Any collected data up until that point will be discarded from all the mediums. If you wish to have your data removed after the completion of the user study, you must make a request within two weeks from the study completion date. After this time, the study data will be used for analysis, and we will no longer be able to remove it. Thus, if you submit a request within the two-week time frame, we will delete your data from all stored mediums.

How to Obtain Results
We will share a summary of the study results once completed. However, individual results will not be provided. Approximately 12 months from now, you can access these results by visiting the lab's website (gem.cs.dal.ca).

Questions
We are here to assist you with any questions or concerns about participating in this research study. Please feel free to contact Aayush Shrestha (ashrestha@dal.ca) with any inquiries, comments, or concerns regarding the study.
If you have any ethical concerns regarding participating in this research, you can also contact the Research Ethics Office at Dalhousie University. They can be contacted at (902) 494-3423 or ethics@dal.ca. Please mention the REB file # 20XX-XXX in your communication.

Consent

By signing below, you acknowledge that you have read and understood the information provided in this consent form and agree to participate voluntarily in the research study described above.

Participant Name: _____

Participant Signature: _____

Date: _____

Demographic questionnaire

Date: Participant Number:

Age:

1. 18-24 years old
2. 25-34 years old
3. 35-44 years old
4. 45 years old and above

Gender:

1. Male
2. Female
3. Other

Visual Acuity:

1. Myopia
2. Hypermetropia
3. Both
4. None
5. Prefer not to say

Orientation and Mobility (O&M) Training

1. Do you have prior experience O&M training?
    a. Yes
    b. No

If yes, the following question will show:

What is your perceived O&M training level?

a. Novice/Beginner
b. Intermediate/Competent
c. Expert/Trainer

VR experience

2. Do you have VR experience?
    a. Yes
    b. No

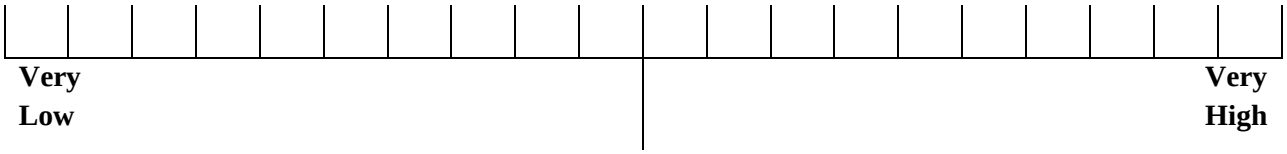
If yes, the following question will show:

3. What did you do in VR?
4. How many hours a week do you spend using VR applications?

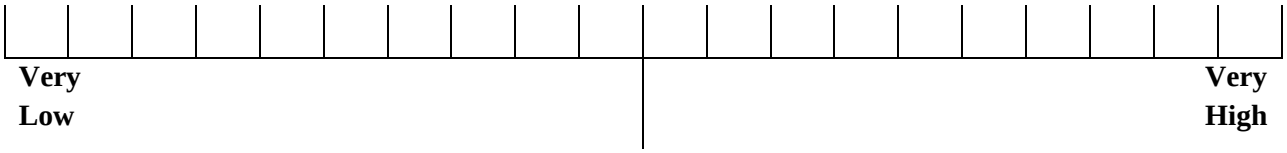
Workload Assessment Questionnaire (NASA TLX)

Date: Participant No:
Task: T2 and T3 Questionnaire version: *With Visuals*

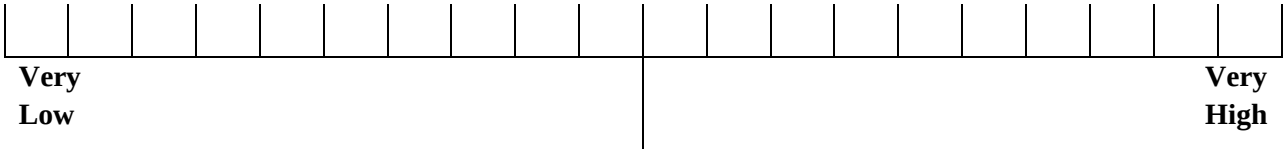
Mental Demand: How mentally demanding was the task?



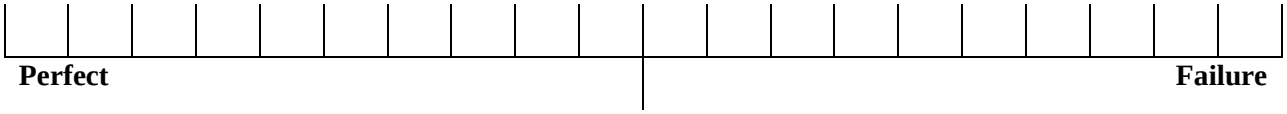
Physical Demand: How physically demanding was the task?



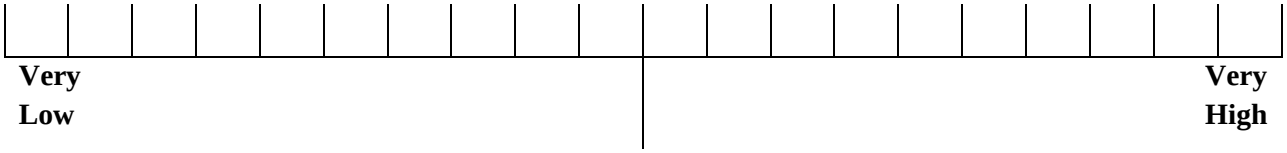
Temporal Demand: How hurried or rushed was the pace of the task?



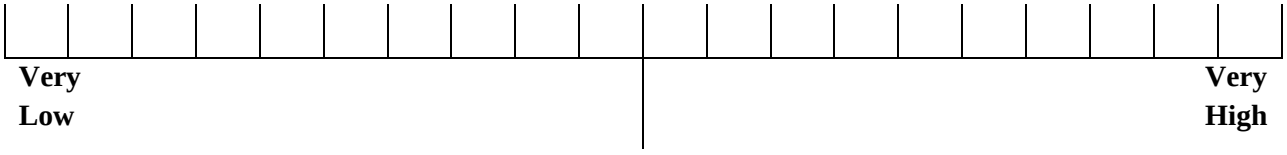
Performance: How successful were you in accomplishing what you were asked to do?



Effort: How hard did you have to work to accomplish your level of performance?



Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?

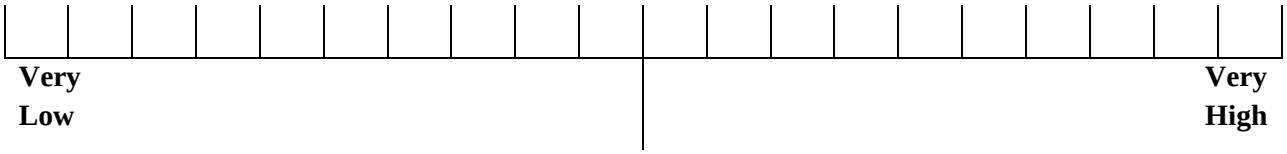


Workload Assessment Questionnaire (NASA TLX)

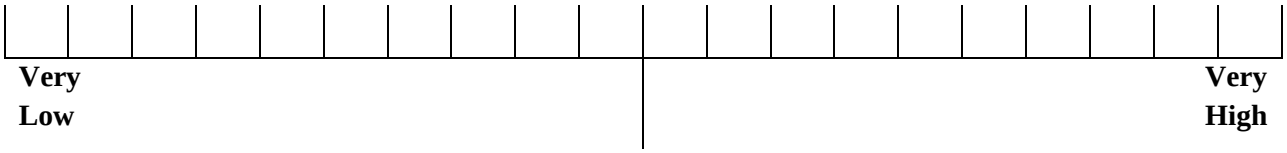
Date: Participant No:

Task: T2 and T3 Questionnaire version: *Without Visuals*

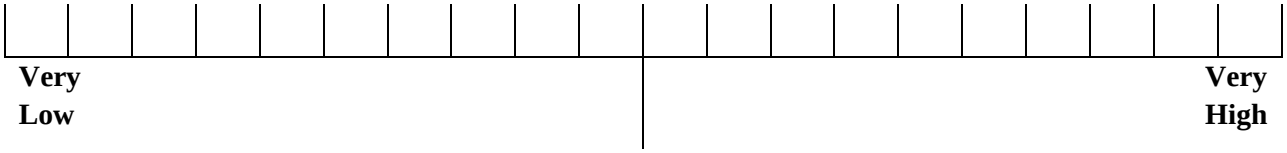
Mental Demand: How mentally demanding was the task?



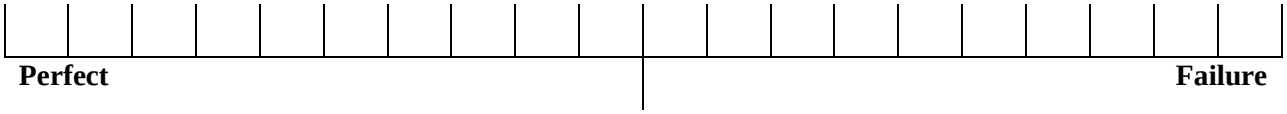
Physical Demand: How physically demanding was the task?



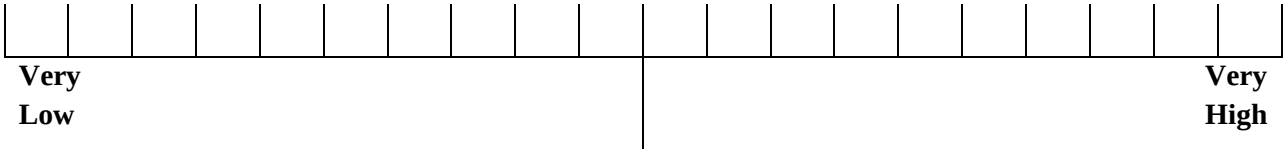
Temporal Demand: How hurried or rushed was the pace of the task?



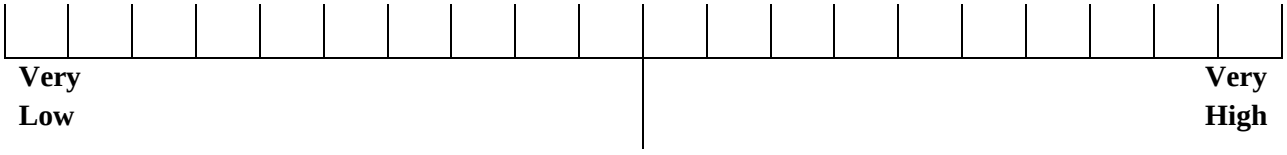
Performance: How successful were you in accomplishing what you were asked to do?



Effort: How hard did you have to work to accomplish your level of performance?



Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?



System Usability Scale (SUS) Questionnaire

Date: Participant No:

Based on your experience *today*, check the box that reflects your immediate response to each statement. Don't think too long about each statement. Make sure you respond to every statement. If you don't know how to respond, check box "3".

		Strongly disagree 1	2	3	4	**Strongly agree** 5
1	I think that I would like to use the system frequently.	☐	☐	☐	☐	☐
2	I found the system to be simple.	☐	☐	☐	☐	☐
3	I thought the system was easy to use.	☐	☐	☐	☐	☐
4	I think that I could use the system without the support of a technical person.	☐	☐	☐	☐	☐
5	I found the various functions in the system were well integrated.	☐	☐	☐	☐	☐
6	I thought there was a lot of consistency in the system.	☐	☐	☐	☐	☐
7	I would imagine that most people would learn to use the system very quickly.	☐	☐	☐	☐	☐
8	I found the system very intuitive.	☐	☐	☐	☐	☐
9	I felt very confident using the system.	☐	☐	☐	☐	☐
10	I could use the system without having to learn anything new.	☐	☐	☐	☐	☐

Interview Questions

Date: Participant No:

1. What role did various audio experiences play for you to get around in the virtual environment? Could you share the different kinds of audio you encountered in the VR space?

2. How realistic were the haptic profiles of the virtual surfaces?

3. What are your thoughts on using a slide-mill for navigation in VR? Do you think it affects the level of immersion?

4. Regarding task 1, do you think you have a preference for feedback from any particular sensory modality, such as audio or haptic? Or do you believe both are equally important for maximum effectiveness?

5. How immersive do you think the system would be for someone with visual impairment?

6. Did this experiment change your level of empathy or awareness towards people with visual impairments? If yes, could you explain how?

7. What is your overall feedback on the system? What improvements do you think could be made?