Acronyms

RIR Room Impulse Response 3

first: Click here

Second: Click here

Contents

User Testing

Once the implementation of the system to allow the user to move themselves around a virtual space had been completed, the plausibility of the methods used were tested. The following sections present the aims of the user tests in full, the procedure required to fulfil the set objectives followed by the results and a discussion.

In total, seven students took part in the user tests, all of which were studying audio related subjects.

2.1 - User Testing Aims

There were a total of 3 user tests, with the third being split into two parts with an identical procedure. The aims of each test were as follows:

Test #1: Investigate the effect of using the synthetic Room Impulse Response (RIR)'s as opposed to the previously used real RIR's used.

Test #2: Investigate how far the user has to be moved before they notice that they have been moved using synthetic RIR's

Test #3.1: Investigate which RIR grid provides the user with the best sense of mobility

Test #3.2: Investigate whether the users opinion changes when using a position feedback system

Before the tests were conducted, each participant was presented with a 'Test Participant Form', informing them of the aims of the tests and the procedures that were to follow. As they were going to be stood inside the speaker array, the answers provided by each participant were taken down on their behalf. At the end of the experiment the answers were checked and signed by the participant assuring that their answers had been taken down accurately. The form provided to the participants can be found in Appendix D.

Before each test, the participants were allowed two 'dummy runs', allowing them to get used to the system without having their answers recorded, with the intention of removing the disadvantage of being unfamiliar with the system for the first few questions of each test. They were also informed that during each test they were allowed to turn their head in the space to obtain a more natural listening experience.

2.2 - TEST #1

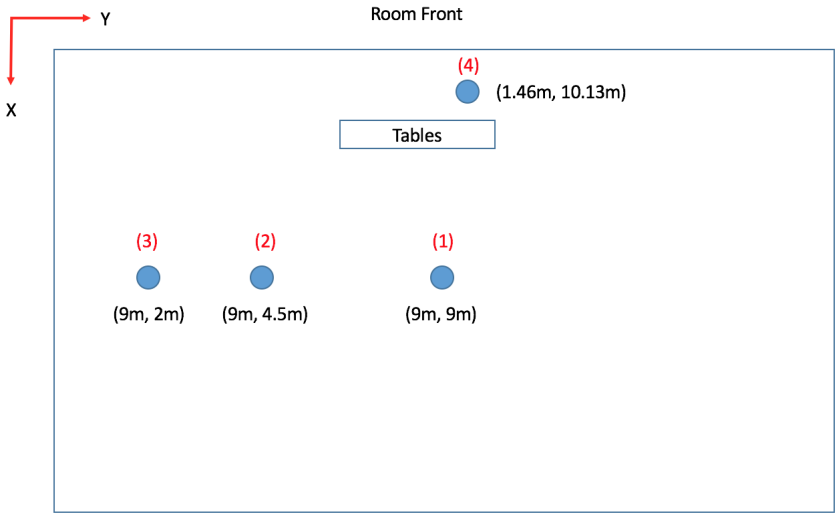
2.2.1) Procedure

To investigate the difference in the perception of distance moved when using either synthetic or real RIR's, the following procedure was carried out:

The participant was told that two methods were going to be investigated during this test, method **A** and method **B**. The participant was not told that in method **A**, the real RIR measurements from Hendrix Hall were going to be used to move them around the room and in method **B** the synthetic RIR's produced in Odeon were going to be used. The participant was told that using method **A**, they were going to be placed somewhere in the virtual space and that they would be asked to say the word 'Bob'. They would then be moved to another position in the space and asked to repeat themselves. This procedure would the be repeated, however this time using method **B**. They were then asked to state whether they felt they had:

1) Moved a **shorter** distance than they had in **A**
2) Moved the **same** distance they had in **A**
3) Moved a **further** distance than they had in **A**
4) I don't know

This was repeated three times where the distances used for mathes A and B were kept the same. For the final two trials, the distances between the two methods were changed. The left of figure 1 shows an illustration of the virtual space indicating where the four RIR locations used for the test are. The black numbers indicate the coordinates of the RIR's relative to the top left corner of the room (note that the x and y axis are opposite to convention due to the way the building was modelled in Google SketchUp), and the red numbers are used to indicate which location the user was moved to during each test, shown on the right in figure 1.



Trail	Real RIR **(A)**		Odeon RIR **(B)**	
	Start	End	Start	End
1	(1)	(2)	(1)	(2)
2	(1)	(3)	(1)	(3)
3	(1)	(4)	(1)	(4)
4	(1)	(3)	(1)	(4)
5	(4)	(1)	(1)	(3)

Figure 1: **Left:** Illustration of the RIR locations used in user test #1. **Right:** Table showing the pairs of positions the participant was moved to, corresponding to the positions shown in the diagram on the left.

2.2.2) Results

The participants answers for user test #1 were taken and averaged across all five trials. Figure 6 shows these results, showing the percentage of correct and incorrect answers given (left) and the percentage of each type of answer given (right). It can be seen that only 23% of the answers given across all trials and participants were correct, indicating there being difficult comparing the two distances moved.

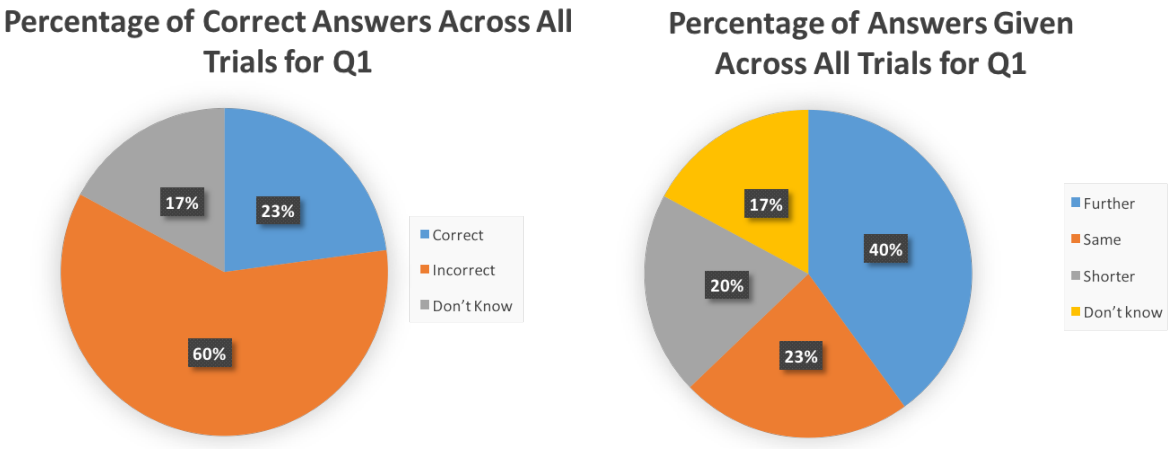


Figure 2: Pie charts showing the results of user test #1

The pie chart on the right shows that more commonly, people thought that they were moving a further distance when the synthetic RIR's were used. It can be seen in the table in figure 1 that the expected answers are as follows:

Trial	Correct Answer
1-3	Same
4	Shorter
5	Further

However, an interesting result can be seen when breaking down the answers given into their respective trials, as shown by the three pie charts in figure 3. When the distance moved was either the same (trials 1-3) or shorter (trial 4), more people tend to answer that they had moved further, more so when they had actually moved a shorter distance. When the distance moved was actually further, the answers are evenly split between 'Further', 'Same' and 'Don't Know'. This negative correlation between expected answer and given answer suggests that the pie chart on the right in figure 6, showing that the majority of people thought they were moving further throughout all trials, is not influence by the fact that people got the answer to trial 5 correct, indicating that it is the use of the synthetic RIR's themselves that cause this perception.

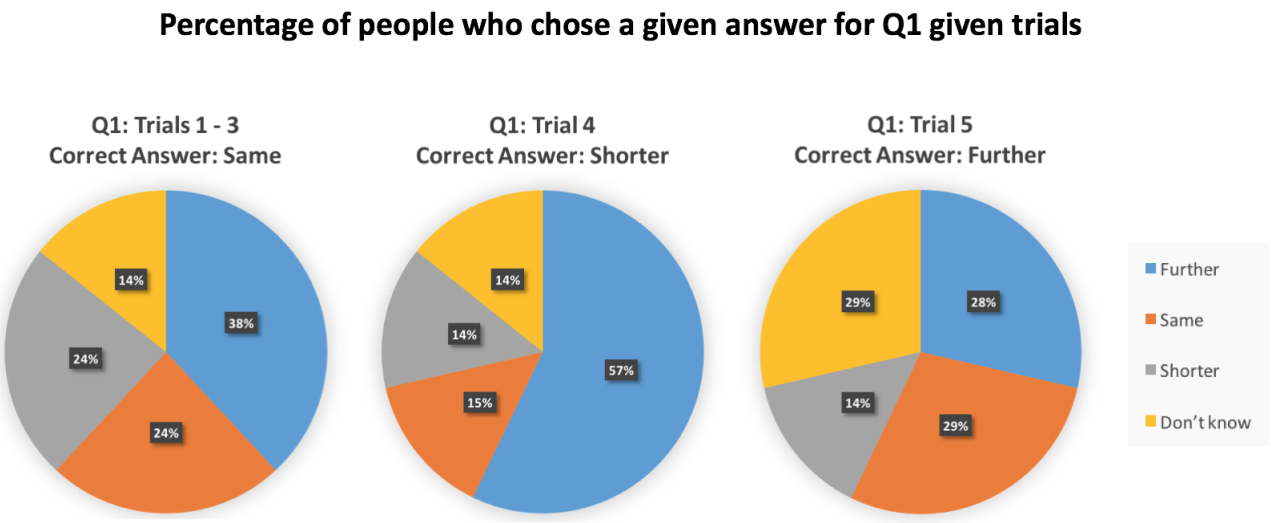


Figure 3: Three pie charts showing the percentage of answers given for: **Left:** Trials 1- 3, **Centre:** Trial 4, **Right:** Trial 5.

2.2.3) Discussion

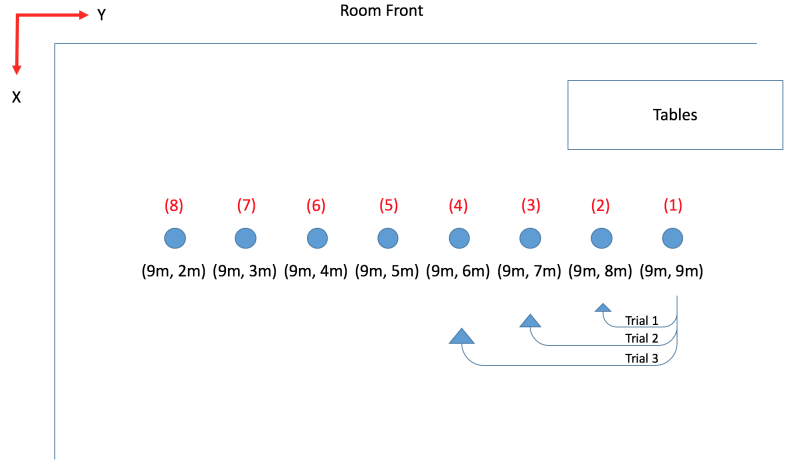
Due to the small percentage of correct answers given, it is apparent that comparing the difference in distance moved is not easy. For the system used, there may be 2 reasons for this:

1) **The test is too hard**
   Asking the participants to not only compare how two different locations sound to each other, but compare that difference to how another two sound compare to each other may have been too much to remember at once. This may have led to participants guessing answer as opposed to giving an answer based on opinion, even though the 'I Don't Know' option was available.
2) **Inaccurate RIR's**
   It has been mentioned in section **?? ??** that due the fact that the RIR's had to be trimmed due to system latency, much needed direct wall reflections are not present for surfaces less than approximately 3.78m away. Though this may effect the ability to accurately access ones location in the virtual space, it does not explain the perception of moving a further distance when using synthetic RIR's than when using real measured RIR's

2.3 - TEST #2

2.3.1) Procedure

The second user test is similar to that of the first test, though a little more simple. Figure 4 shows 8 RIR locations, where (1) is in the centre of the room. The participant was placed at position (1) and asked to say the word 'Bob'. They would then be moved closer to the left wall, asked to repeat themselves and asked whether they thought they had moved or not, simply answering yes, no or 'I Don't Know'. This was done 7 times, moving the participant a further distance each time. The table on the right in figure 4 shows the start and end position for each trial.



Trail	Position (x,y)	
	Start	End
1	(1)	(2)
2	(1)	(3)
3	(1)	(4)
4	(1)	(5)
5	(1)	(6)
6	(1)	(7)
7	(1)	(8)

Figure 4: **Left:** Illustration of the RIR locations used in user test #2. **Right:** Table showing the pairs of positions the participant was moved to, corresponding to the positions shown in the diagram on the left.

2.3.2) Results

Figure 5 shows a line graph of the results obtained from user test #2, showing on how many participants answered 'Yes', 'No' or 'Don't Know' for each of the trials.

The original hypothesis to this test was that the participants were unlikely to notice that they had moved for the first few trials as they were being moved such a short distance (1m, 2m), with the expectation that they would notice when they were being moved much larger distances, hence the reason there were moved 1m closer to the wall in each trial. However, it was found that all participants answered 'Yes' for the first trial (movement of 1m towards the left wall) and all other trials resulted in a number of participants giving an answer other than 'Yes'. Instead of a positive correlation between distance moved and 'Yes' answers given, there appears to be a dip from trials 2-4

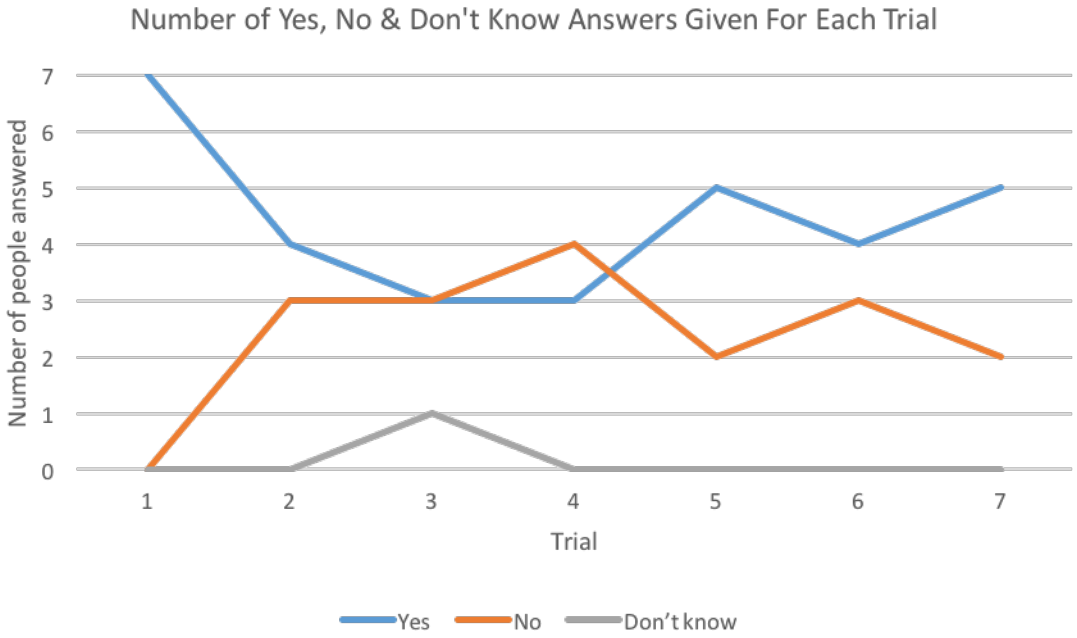


Figure 5: Line graph of the results from user test #2 showing the number of participants who answered 'Yes', 'No' or 'Don't Know' for each of the trials.

2.3.3) Discussion

Comparing the results to the original hypothesis, excluding the first two trails, there seems to be more people noticing movement as the distance moved increases. These first two trials may have been subject to a bias, where the user is expecting to be moved. This however can not be backed up and remains a speculation.

Other causes for these results could be one of the following:

1) That the RIR's used do not contain enough information regarding the users location.
2) The participants answering 'No' simply don't know or do not hear that they expect to hear when moving in a room.
3) The inconsistency in repeating themselves has more of an effect on their perception of location than the actually room acoustics.

2.4 - TEST #3

2.4.1) Procedure

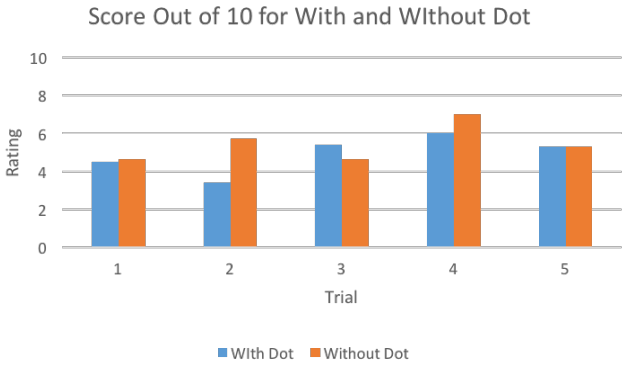
The participants were presented with an iPad and informed that it could be used to draw a path within the virtual space which they would then be moved around. They were asked

Five trials were run, each using a different RIR grid, previously explained in section **??** **??** and displayed in section **??** **??** in figure **??** (1m separation) and in B Appendix B as figures 11,12,13,14 (2m - 5m separation respectively). The following table shows which trial used with RIR grid, stating the distance between RIR locations and the number of RIR locations within that grid:

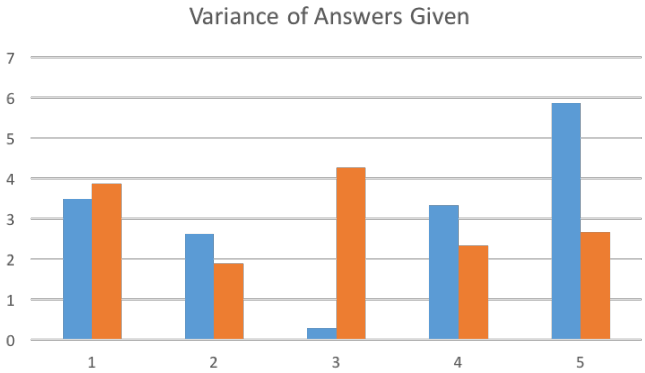
Trial	RIR Location Separation	Number of Positions Available
1	1m	240
2	2m	112
3	3m	25
4	4m	12
5	5m	9

In each trial, the participant was asked to draw a path and listen to an audio sample (an audio sample **[REFERENCE AUDIO SAMPLE]** was played in place of the participant speaking/singing to provide a constant sound source as determining movement would be difficult with inconsistent speaking). They were then asked to rate on a scale of 1-10 the quality of mobility, where 1 = extremely "jumpy" movement and 10 = completely smooth movement, or to give the answer 'N/A' if they had difficulty telling whether they were moving or not.

2.4.2) Results



(a) A



(b) B

Figure 6: Pie charts showing the results of user test #1

2.4.3) Discussion

2.5 - User Test Summary

Appendices

APPENDIX A

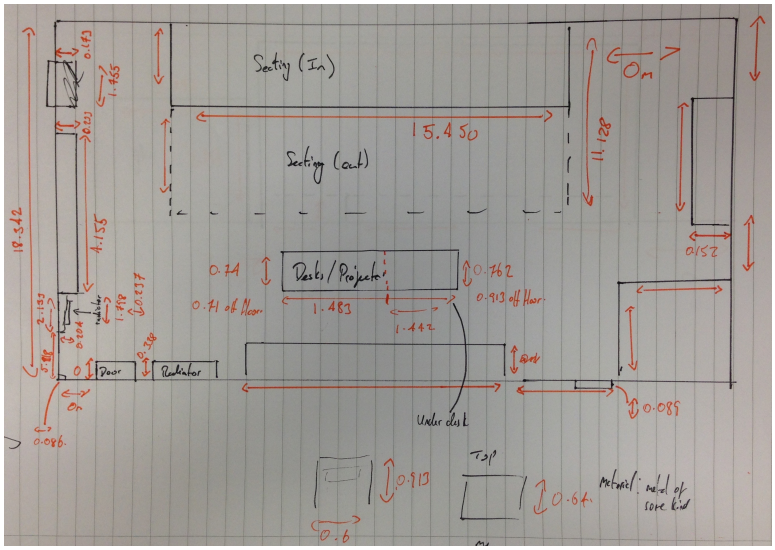


Figure 7: Annotated blueprint of Hendrix Hall from a birds-eye view

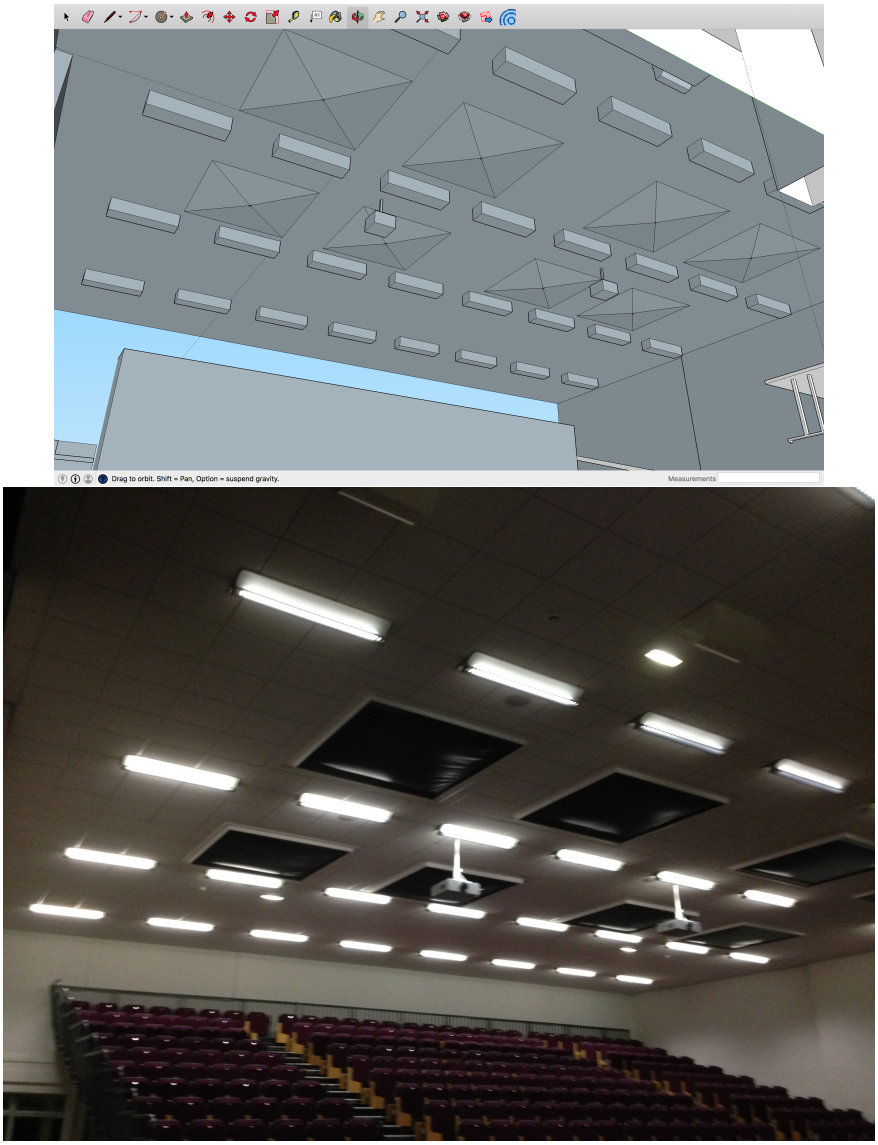


Figure 8: Real Vs SKU Roof

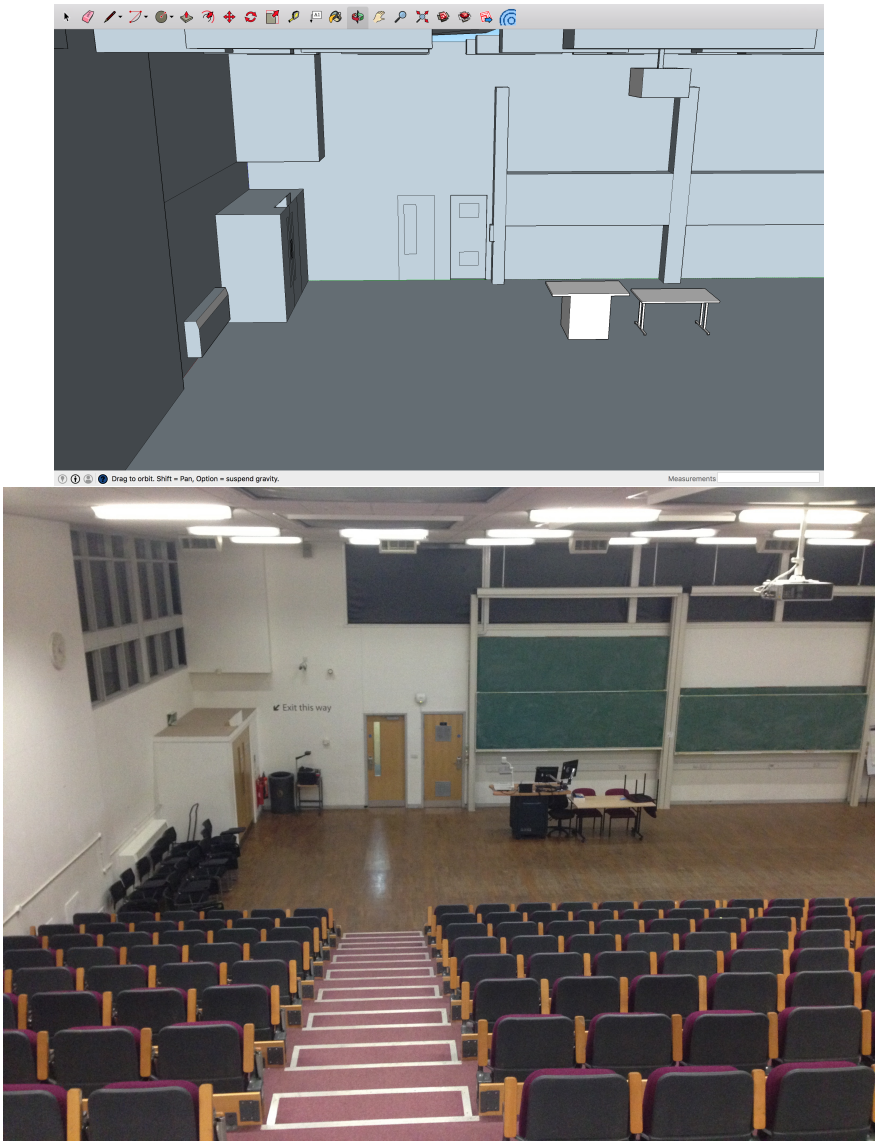


Figure 9: Real Vs SKU Seating Area

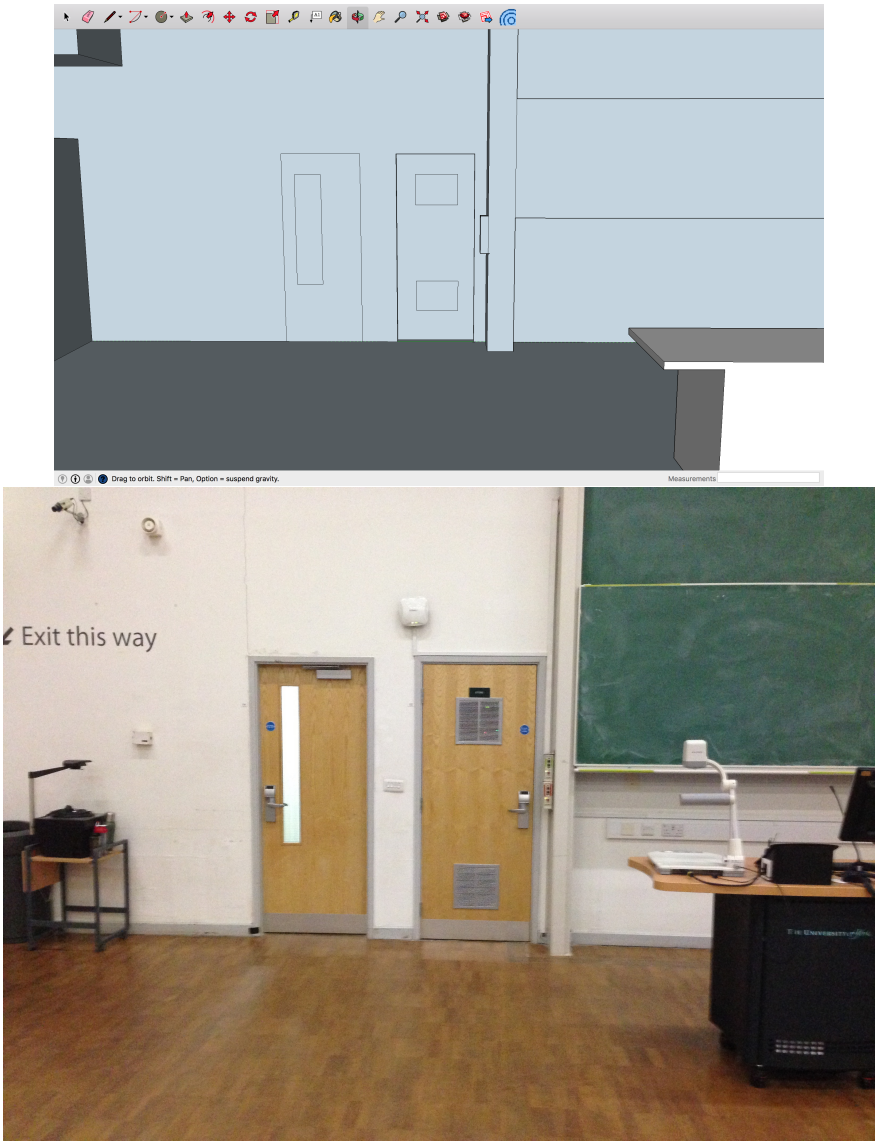


Figure 10: Real Vs SKU Door

APPENDIX B

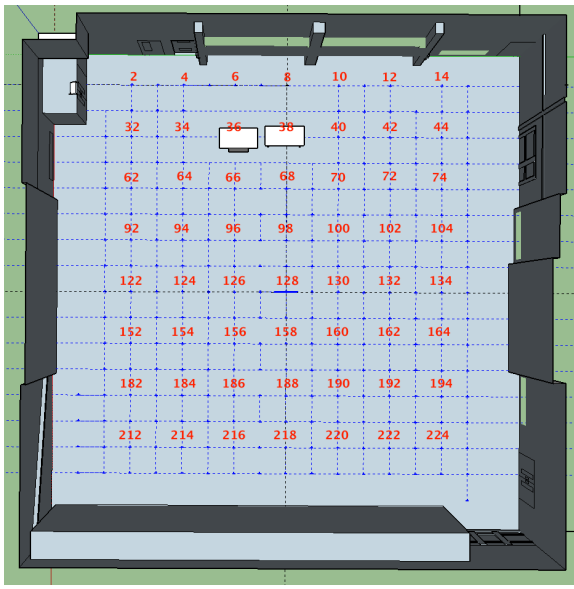


Figure 11: RIR grid with 2m separation

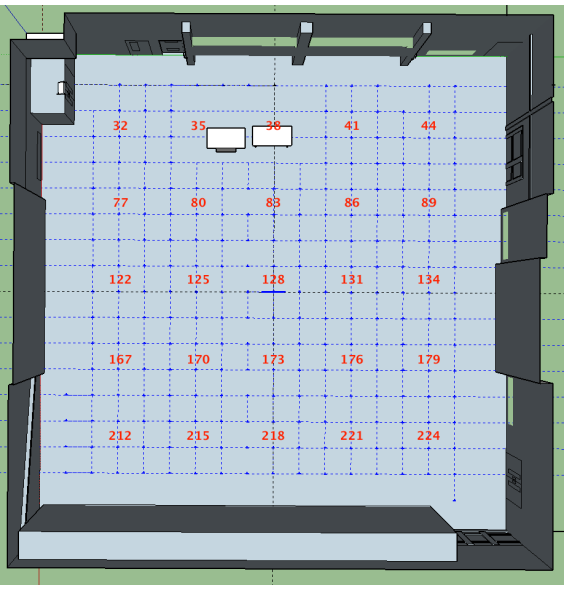


Figure 12: RIR grid with 3m separation

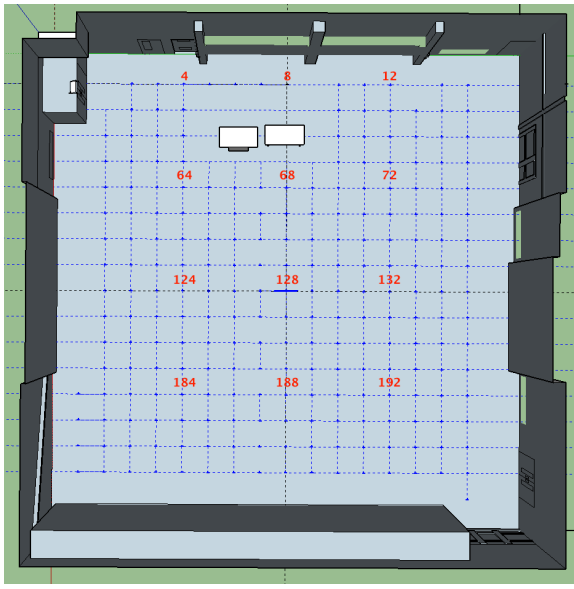


Figure 13: RIR grid with 4m separation

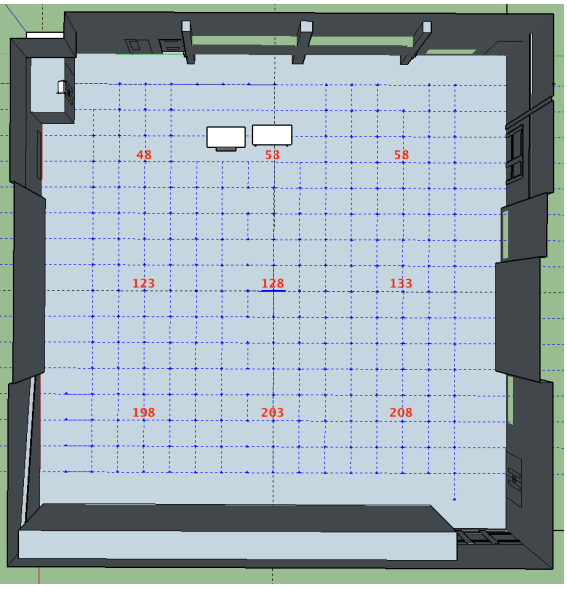


Figure 14: RIR grid with 5m separation

APPENDIX C

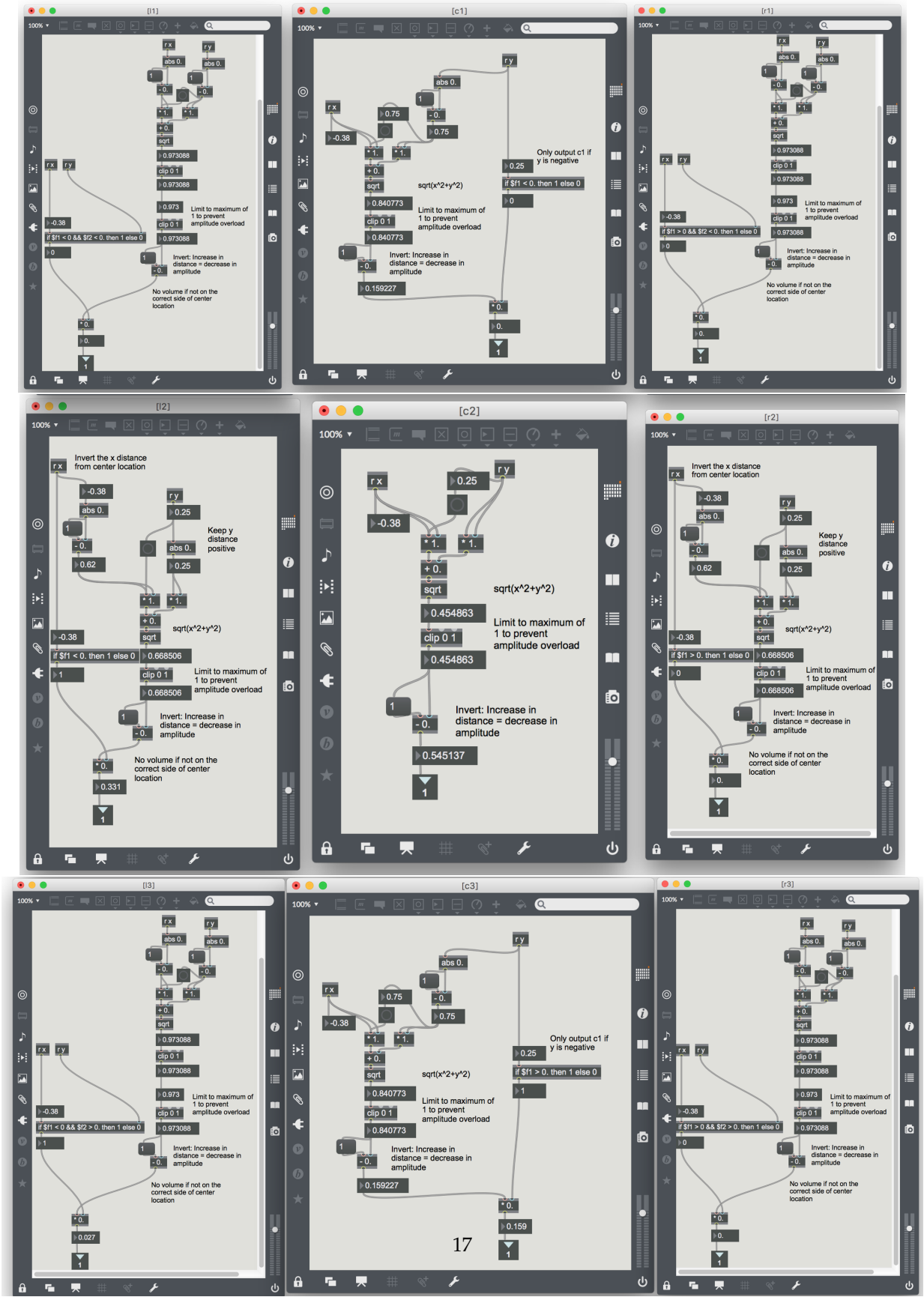


Figure 15: Overview of the individual panning algorithms used in iteration 1.

```
inlets = 5;
outlets = 5;

//Create arrays to store previous positions
var xArray = new Array(2);
var yArray = new Array(2);

var windowSize = new Array(2);

//Variables to use for file searching
var fileX, fileY, search;

//Defines how to split up the grid
var numberOfMeters;

//Loads appropriate files given users finger coordinates
function msg_int(input){
 if(inlet == 0){
  xPos = input;
 } else if (inlet == 1){
  yPos = input;//Add off set to start at (0,1)
 } else if (inlet == 2){
  windowSize [0] = input;
 } else if (inlet == 3){
  windowSize [1] = input;
 } else if(inlet==4){
  numberOfMeters = input;
 }

 //Split into sections
 if(numberOfMeters == 3 || numberOfMeters == 5){
  //Even grid for 3m and 5m
  xPosition = (xPos/windowSize[0])*(numberOfMeters);
  yPosition = (yPos/windowSize[1])*(numberOfMeters);
 } else if (numberOfMeters == 4 || numberOfMeters == 8){
  //4m separation requires different x,y coordinate scaling
  xPosition = (xPos/windowSize[0])*(numberOfMeters-1);
  yPosition = (yPos/windowSize[1])*(numberOfMeters);
 } else{
  //Extra row for others
  xPosition = (xPos/windowSize[0])*(numberOfMeters);
  yPosition = (yPos/windowSize[1])*(numberOfMeters+1);
 }

 //Round to nearest value
 xSection = Math.round(xPosition);
 ySection = Math.round(yPosition);

 //Start the lcd grid sections from column 1 row 1 instead of column 0 row 0
 if(xSection == 0){
  xSection = 1;
 }
```

```
53 if(ySection == 0){
54  ySection = 1;
55 }
56
57 //Distance in % away from center of section
58 xBetween = 2*(xPosition - xSection); //x2 to get 100%
59 yBetween = 2*(yPosition - ySection);
60
61 //Which RIR to load in centre location
62 outlet(0,xSection);
63 outlet(1,ySection);
64
65 //Output panning values
66 outlet(2,xBetween);
67 outlet(3,yBetween);
68
69 //Store current location
70 xArray[0] = xSection;
71 yArray[0] = ySection;
72
73 //If either coordinate is changed search for new files
74 if(xArray[0] != xArray[1] || yArray[0] != yArray[1]){
75
76  if(xArray[0] != xArray[1]){
77   //Store previous value
78   xArray[1] = xArray[0];
79   X = xArray[0];
80  }
81
82  if(yArray[0] != yArray[1]){
83   yArray[1] = yArray[0];
84   Y = yArray[0]
85  }
86
87  //Output user location within grid
88  if(numberOfMeters == 4 || numberOfMeters == 8){
89   fileNumber = X + ((numberOfMeters-1)*(Y-1)); //Requires different algorithm for 4m
       due to different grid shape
90  } else {
91   fileNumber = X + ((numberOfMeters)*(Y-1));
92  }
93  outlet(4,fileNumber);
94 }
95}
```

Sections/Appendix/AppendixA/Code/loadFilesLogic.js

APPENDIX D

Test Participant Form

You have volunteered to partake in two user tests that should take no longer than 30 minutes to complete.

Test Descriptions

The VSS (virtual singing studio) is a system that is used to simulate the acoustics of another room. The system can be used by standing in the centre of the speaker array and singing into a head mounted microphone. By wearing the provided head-tracking device, you can turn in the virtual space by turning your head/body.

Test #1

This test aims to investigate the perception of movement within the virtual acoustic environment when using two different methods: Method **A** and Method **B**. You will be asked to step inside the VSS and say the word "Bob". Your location within the virtual space will then be changed and you will be asked to produce another sound. This process will then be repeated a second time but this time using method **B**. You will then be asked to state whether method **B** felt like you had:

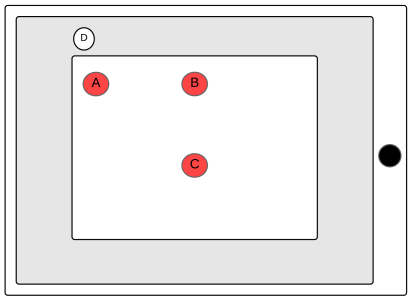
Moved a **shorter** distance than I had in **A**
Moved the **same** distance as I had in **A**
Moved a **further** than I had in **A**
I don't know

This process will be repeated 5 times in total.

Test #2

Part 1: You will be asked to step inside the VSS and to sing or produce a noise. After a short amount of time you will be asked to do the same again. You will then be asked whether you feel you have changed location or not with a simple Yes/No answer. This will be repeated 8 times.

Part 2: In this part of the test, you will be asked to change your location within the virtual space yourself by tapping on a location or dragging your finger around the iPad provided for you. You will be asked to rate on a scale of **1 - 10** how free you feel you can move about the room with **1** being a *jumpy movement* and **10** being *complete freedom to move without limitations*. You will also be given the opportunity to add comments to further explain you score if you wish.



To the left is a diagram of an iPad. **A**, **B**, and **C** indicate where parts of the room can be located. When situated in the VSS, you will start in the center of the room **(C)** facing towards the front of the room **(B)**.

A = Top left corner of the room
B = Front of the room
C = Centre of room
D = Button to calibrate head tracker

Answering Question

Note that when you're within the VSS it will be difficult to write down your answers to the questions asked. Therefore you will be asked to answer verbally and your answers will be taken down for you. You will be asked at the end of the test to check that your answers have been taken down truthfully.

Information and Consent

Experimenter: _____

Please read the following statements and tick the boxes on the right hand side to indicate that you understand and agree.

I understand that at any point I may choose to withdraw from the experiment	☐
I understand that I may omit answers to any questions	☐
I agree that I am here voluntarily	☐
I understand and agree that the experimenter conductor will be observing the experiment	☐
I agree that the system being used has been explained to me	☐
I agree that the point of this experiment has been explained to me	☐

Participant Signature: _____

Answer Sheet

Participant Number: _____ Date: _____

Test #1

Question 1: Please state whether you feel you have:

Moved a **shorter** distance than I had in **A**
Moved the **same** distance I had in **A**
Moved a **further** distance than I had in **A**
I don't know

Trial	**Score**			
	Shorter	Same	Further	Don't Know
1	○	○	○	○
2	○	○	○	○
3	○	○	○	○
4	○	○	○	○
5	○	○	○	○

I agree that the answers that have been taken down on my behalf are correct □

Participant Signature: _____

Participant Number: _____ Date: _____

Test #2 - Part 1

Question 2: Do you feel you have changed location within the room?

Trial	**Answer**
1	YES/NO
2	YES/NO
3	YES/NO
4	YES/NO
5	YES/NO
6	YES/NO
7	YES/NO

Test #2 - Part 2

Question 3: Please rate on a scale of **1 - 10** the mobility within the virtual space where **1** = Extremely "jumpy" movement and **10** = Completely smooth movement or please select "N/A" if you can not tell you are moving.

Trial	**Score**										**N/A**
1	1	2	3	4	5	6	7	8	9	10	
	○	○	○	○	○	○	○	○	○	○	○
2	1	2	3	4	5	6	7	8	9	10	
	○	○	○	○	○	○	○	○	○	○	○
3	1	2	3	4	5	6	7	8	9	10	
	○	○	○	○	○	○	○	○	○	○	○
4	1	2	3	4	5	6	7	8	9	10	
	○	○	○	○	○	○	○	○	○	○	○
5	1	2	3	4	5	6	7	8	9	10	
	○	○	○	○	○	○	○	○	○	○	○

Comments:

I agree that the answers that have been taken down on my behalf are correct □

Participant Signature: _____

Question 4: Please rate on a scale of **1 - 10** the mobility within the virtual space where **1** = Extremely staggered movement and **10** = Completely smooth movement or please select "N/A" if you can not tell you are moving.

Trial	**Score**										**N/A**
1	1	2	3	4	5	6	7	8	9	10	
	○	○	○	○	○	○	○	○	○	○	○
2	1	2	3	4	5	6	7	8	9	10	
	○	○	○	○	○	○	○	○	○	○	○
3	1	2	3	4	5	6	7	8	9	10	
	○	○	○	○	○	○	○	○	○	○	○
4	1	2	3	4	5	6	7	8	9	10	
	○	○	○	○	○	○	○	○	○	○	○
5	1	2	3	4	5	6	7	8	9	10	
	○	○	○	○	○	○	○	○	○	○	○

Comments:

I agree that the answers that have been taken down on my behalf are correct □

Participant Signature: _____