Worksheets

accompanying "Measuring the Effect of Control-Display Gain and Virtual Body Representation in Range of Motion Exercises".

Worksheets

MTA 18736

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Medialogy

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Contents

1. Transcriptions

The transcription from the expert interview can be found in appendix A

2. Representation of VR

2.1 Body

For the body of the avatar Adobe Fuse CC (Beta)[1] was used. Fuse is a free program which allows the user to create human avatars of different sizes, shapes and colours.

The process consists of choosing individual parts as the avatar assembles before you. Starting with the head, you afterwards pick torso, arms and legs, respectively. You also have the choice of changing the skin colour, hair, facial hair and clothes. We chose a body type that seemed right in the middle between athletic and over-weight and with with a simple t-shirt and shorts as we imagined that might be casual wear at home.

After the avatar was selected there are several options which enable you to change stance and/or animations. As we wanted it rigged to the players movement a simple t-pose was chosen and without any animations as seen on Figure 2.1.

Figure 2.1: The standard t-pose from Adobe Fuse CC (2018).

As we wanted this model to be used in first person we removed the head to prevent any clipping to happen between the player and the avatar. Regarding the arms, even with inverse kinematics there might be inaccuracies between the physical movements and the ones presented in the game, so therefore we also removed the arms. The hands are still represented, though this is done with SteamVR's own hand models. The final model can be seen in Figure 2.2

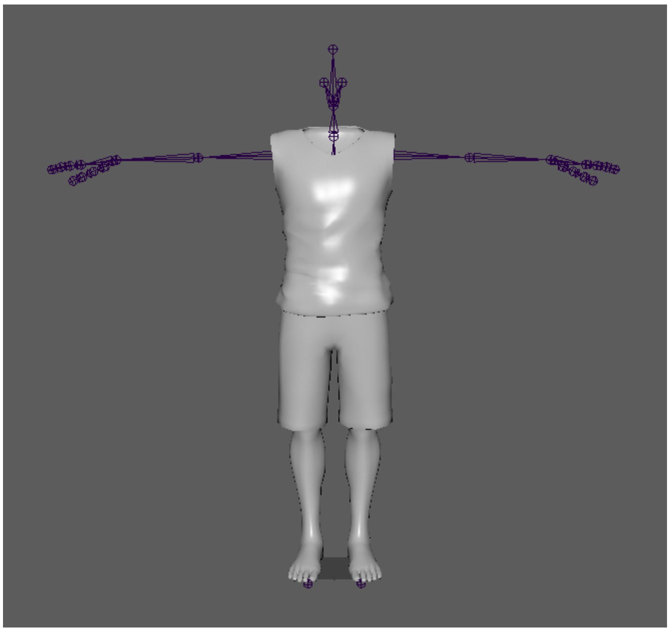

Figure 2.2: The final model used in the game (untextured)

2.2 Hands

The hand models we used were included in SteamVR 2.0, and using the default skeletal system pressing the squeeze buttons or the trigger made the hand do a grab motion. When picking up objects, the plugin allowed us to choose from several grab poses, and as we instructed the participants to pick up objects with the trigger, we chose a grab pose where the hand uses its thumb, index and middle fingers to pick up something.

Figure 2.3: SteamVR's handmodel as viewed by the player.

2.3 Rigging

As Fuse made the skeleton, the next thing was to rig it to our trackers in Unity. We imported the model into Unity, which automatically created an avatar based on the rigging and the "Humanoid" selection under "Animation Type" during import. This created avatar was then used later in scripting to bind the character's bones to trackers, and legs to predetermined spots on the floor in addition to unity's built-in kinematics system to achieve a simple but believable body representation.

3. Scaling experiment

During the semester, before full implementation of the system began, a test involving scaling was carried out to examine whether there was a point where scaling became apparent to the users. While there are existing studies experimenting with this threshold, it was necessary to look for possible differences that might arise when using the setup and system used in this project.

3.1 Participants

The test was carried out on 10 test participants from the 7th semester of Medialogy. Every participant had previous experience with virtual reality prior to this experiment. Participants were of similar age and had no preexisting condition of chronic pain. One participant reported having slight pain in the torso, and another reported discomfort caused by the weight of the HMD. There were no exclusion factors set. Every subject has completed the test.

3.2 Task

The procedure involved a simple body rotation task that required rotation of the neck or torso around the Y-axis. This movement was used to complete a target-matching task in a virtual environment using the HTC Vive.

3.2.1 Virtual Environment

The virtual environment consisted of a simple white room, with a blue square in the middle that indicated where the participants should be standing. At angles -70°, 0° and 70°, there were three rectangular polygons at roughly eye level. The one at 0°was coloured blue, and the two others were coloured red. Additionally, the scene included a fourth polygon, coloured green, which was always perpendicular to the head-mounted display (HMD), following it around as the participants' head turned. The blue one was used as an indicator for the user that they were looking straight ahead, and the two red ones were the target objects the green one had to be matched to. Matching the green polygon to the red ones needed not be 100% precise as the point was to provide the user with a fixed point until which the rotation was required to be done.

3.3 Procedure

The test was split into two conditions, with each condition having 10 movement pairs. The movement pairs required subjects to perform the same action twice, once with scaling and once without scaling. The two conditions were positive movement scaling (gain > 1) and negative movement scaling (gain < 1). All test subjects completed both conditions, doing positive scaling first and negative scaling second. Scaling ranged from 0.2 - 2 and from -0.2 - -2, and increment steps were 0.2 in both (positive and negative) conditions. Following the completion of a movement pair, participants were asked whether they noticed any difference between the two movements. After they gave response, the scaling was increased or decreased by

3.4 Raw results

The participants' responses were saved down in Google Sheets worksheets, with the response put down in the column of the movement they indicated felt different. The column of the scaled movement was marked with an "*". If they did not report feeling difference, both columns were marked with a "/" in the response fields.

Unfortunately, the results are varied, and the test could have possibly benefited from either presenting the participants with a two-alternative forced choice question. In that case, the participants would have been required to choose between the unscaled and scaled motion and tell which one they felt scaled. This however could have possibly skewed the results, where participants would have noticed scaling earlier than the normally would have due to being forced to pick. Raw results can be found in appendix B, and a combined table for easier overview is included as well.

4. Game design

The game is designed around the purpose of the user rotating their spine. The player is placed in the center of a circular table. This is to discourage movement by the player, and to ensure the entire surface of the table is reachable without movement. Along with the HMD the user is also equipped with two trackers and two controllers. One tracker is located on the back of the hip, while the other is strapped between the shoulder blades as seen on Figure 4.1. The angle between the two trackers is used to calculate the rotation of the back. The two controllers are used to grab the fruit after it is spawned into a bowl located in front of the player.

Figure 4.1: The setup of the two trackers on the hip and back.

The player gains points by increasing the angle of the trackers and dropping the fruit on the table. The higher the angle, the more points. Following the movement a line of green orbs show the current angle between the two trackers, indicating the potential points the player can achieve in their current position, shown in Figure 4.2. Once a fruit has been dropped, the spheres from the last movement remain so the player may relate their next rotation to this in an attempt to gain more points. At the end of the line of spheres (with the angle of the back tracker) the points for the rotation is displayed. The total amount of accumulated points is also visible on a monitor in the scene.

We chose to have these visuals elements located in the world rather than in the head reference frame as to make them less intrusive for the player. Having the user interface elements closer to the waist/ground makes it easily available without it cluttering the view [2].

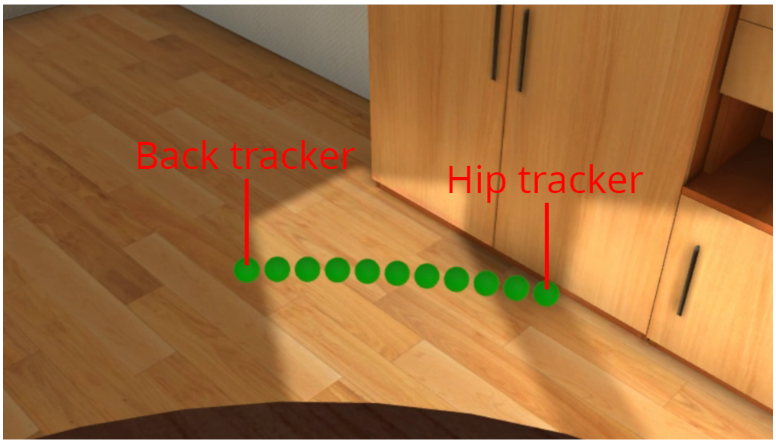

Figure 4.2: The green orbs showing the angle between the two trackers.

Following the playcentric approach outlined by Fullerton [3], the game was developed through a series of iterative designs. The game was, from the beginning, centered around encouraging the player to rotate their spine in a standing position. Different ideas meant to cause encouragement were considered with some tested internally. These ideas include: having the player chose whether they want to increase or decrease difficulty (scaling), having specific drop areas for the fruit as well as having a mirror enabling the player to evaluate their own movement from a different perspective.

5. Assets

As part of the gamification process some assets were developed and/or imported to make the scenes more lifelike.

5.1 SteamVR

In order to make the game work in VR, we used the SteamVR [4] plugin created by Valve. It features prefabs that automatically work with the HTC Vive, and provide additional options such as representing the controllers as hands, and useful scripts to make the objects interactable in VR.

5.2 Environment

For the environment the asset "Pack Gesta Furniture #1" was used [5]. To save time and resources we chose to download a premade asset. The asset consists of a fully furnished room and a window with a curved plane outside for the background. The room has lights baked into the textures, but this should not pose any issues as the participants are not going to move around (and thereby in front of the lightsource). There is also a directional light matching the suggested direction of the baked light, leaving shadows cast from the objects in the room.

Figure 5.1: Pack Gesta Furniture #1 asset pack

5.3 3D objects

Several individual 3D assets were created for the project. Each object was created using Maya [6] and afterwards textured in Substance Painter [7]. Assets (a), (b) and (c) seen on Figure 5.2 are the fruits the user interacts with. They were all chosen for their rounded shape and made from a low polycount sphere with their details stemming from their texturemaps. Asset (d) is a wooden bowl which was created to prevent the spawned fruit from rolling around after spawning as they all have spherical colliders. As Unity [8] has a polygon limit of 256 for a collider another, lower resolution, model was created in the shape of the bowl to serve this purpose. These four elements all use materials downloaded from the Substance Share website [9, 10, 11, 12]. Finally we have asset (e) which is the table surrounding the user. The purpose is to encircle the user, making the entire surface of the table reachable. The texture also includes a two-sided arrow with a small apple and orange on either side. These are placed to indicate the direction the user is supposed to sort the apples and the oranges.

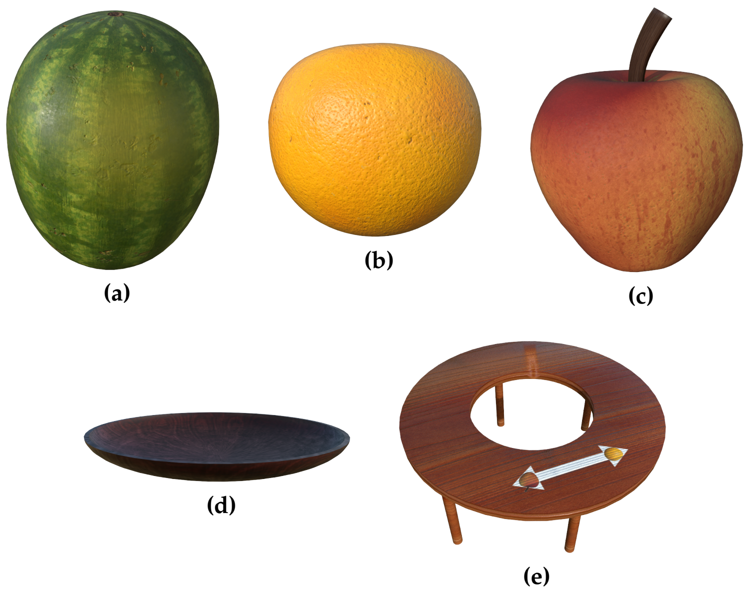

Figure 5.2: All the created 3D assets for the project.

6. Implementation in VR

6.1 Applying Control-Display Gain

The control-display gain in the prototype works on the basis of scaling the Y axis rotation of the HMD by a set percentage. The way SteamVR updates the image seen in the HMD prevents directly altering the virtual HMD's rotation, so there are three possible solutions to do it: Adding a parent object to the HMD in Unity and rotating that, Adding a second camera, rotating it and rendering its image to the HMD, and rotating the scene around the camera. After experimenting with the first two methods, we decided to implement the rotation of the world around the HMD. The scaling is implemented in the *WorldScaling* class. It currently only scales the Y axis rotation, however it has been written in a way that it can be expanded to the other axes as well. First, the class takes the Y axis rotation of the HMD in degrees, and applies the appropriate scaling to it, which is the current multiplication stage as an integer times a fixed 3% scaling. This number is then inverted, as it will be applied to the scene, this way with e.g. a 10% positive scaling, a 30 degree rotation to the right will result in the scene rotating 3 degrees to the left, making the user perceive a 33 degree rotation to the right. In the ScaledRotation method shown in Code 6.1, the HMD's position is saved, then the scaled rotation is applied to it, this way the position of the scene can be altered as if it is rotating around the HMD. Following this, the rotation and the translation are applied to the scene.

The multiplication steps can be changed in three different ways, but only after the trackers on the users' backs have been calibrated. The first way is manually changing it with a slider in the inspector, the second is an automatic scaling based on the amount of fruit sorted, and the third ups the multiplication when the space button is pressed, based on the amount of fruit placed, with a step going up every four placed fruits.

Code 6.1: Rotating and moving the scene objects

```
void ScaleRotation(float trackedAngle, float multiplier, Axis axis)
{
    Vector3 originToHMD = new Vector3(HMD.position.x, 0, HMD.position.z);
    float angle = trackedAngle;
    if (angle > 180f)
    {
        angle -= 360f;
```

```
    }
    Quaternion rot = Quaternion.AngleAxis(angle * multiplier,
        ChooseAxis(axis));
    HMDtoOrigin = rot * originToHMD;
    scaledRotation = angle * multiplier;
    transform.localEulerAngles = MakeScaledRotation(scaledRotation, axis);
    transform.position = MakeScaledTranslation(HMD.position - HMDtoOrigin,
        axis);
}
```

6.2 Item Spawning

The fruits for sorting are spawned by the *ItemSpawner* class. It uses two prefabs, both with the *ItemToPlace* scripts attached. If the trackers on the users' backs have been calibrated, the fruits can begin spawning. The class has two ways of spawning the fruits: The first is the "game" mode, where the fruits continuously spawn until a maximum number of spawned fruits are reached. In the other method, which we used for testing, the fruits are spawned manually, with a one second interval between. This is handled by the SpawnItems coroutine. The spawner alternates between items by taking mod{2} of the current item count, and selecting the result from the prefab array. The coroutine is shown in Code 6.2.

Code 6.2: The coroutine responsible for spawning items

```
IEnumerator SpawnItems()
{
    spawning = true;
    if (itemCount < maxItems)
    {
        for (int i = 0; i < maxItems; i++)
        {
            int objectID = itemCount % 2;
            itemCount++;
            GameObject fruit = Instantiate(items[objectID], spawnPoint,
                Quaternion.identity);
            ItemToPlace fruitScript = fruit.GetComponent<ItemToPlace>();
            fruitScript.id = objectID;
            yield return new WaitForSeconds(1f);
        }
    }
    spawning = false;
}
```

6.3 Tracking Back Angle

The *CalculateBackAngle* class uses the rotation of the HMD and the two Vive trackers attached to the users' hips and upper back to calculate the absolute rotation of their hips, back and head, and the differences inbetween. First, the trackers and HMD have to be calibrated to zero, this is done by multiplying each tracker's and the HMD's rotation by their inverse. After this calibration, the absolute rotations are represented by the Y value of their local Euler angles. The difference between trackers is calculated by multiplying one trackers rotation by the other's inverse, resulting in the difference between rotations. The Y value of this rotation's Euler angles is the difference in degrees. These expressions can be seen in Code 6.3. If this value is above 180 degrees, 360 is subtracted from it, so that right turns are between 0-180 degrees and left turns are between 0-(-180) degrees. The hip and back rotation angles are then passed to the angle marker manager, so they can be represented for the user.

Code 6.3: Calculating the back rotation angles in the Update method

```
...
Quaternion hipRotQ = hipTracker.localRotation * hipZero;
Quaternion backRotQ = backTracker.localRotation * backZero;
Quaternion headRotQ = headTracker.localRotation * Quaternion.AngleAxis(180,
    headTracker.up) * headZero;
Quaternion backHipRotAngle = backRotQ * Quaternion.Inverse(hipRotQ);
Quaternion headBackRotAngle = headRotQ * Quaternion.Inverse(backRotQ);
backHipRotDifferenceEuler = backHipRotAngle.eulerAngles;
headBackRotDifferenceEuler = headBackRotAngle.eulerAngles;
...
```

6.4 Visualizing Back Angle

The *AngleMarkerManager* class is responsible for visualizing the rotations of the back and hip, and the difference between them. This is done by showing spheres in an arc around the player, starting from their hip rotation and ending at their back rotation. 180 spheres are initialized, starting from in front of the player. This is done with a simple for loop, where the iterator goes from 0 to 180, and the X and Z coordinates of the spheres are the Sin and Cosine of the double of the iterator. With this method, the order of the speheres represent the angle they're placed at divided by two. When the ShowMarkers method is called, the two angle arguments are divided by two, floored, then used as the start and end of a for loop to activate the markers. As seen in 6.4, if one of the angles given to the method are negative, normally the entire arc around the trackers would activate, so in this case, after activation, the spheres are "inverted", so the correct ones show up and the incorrect ones hide. To show the arc live, in the Update method of the *CalculateBackAngle* class, the HideMarkers method is called, and after this, in the LateUpdate method, ShowMarkers is called with the new values.

Code 6.4: Showing the correct markers in the arc

```
public void ShowMarkers(int start, int end)
{
    bool invert = false;
    if ((start < 0 && end >= 0) || (end < 0 && start >= 0)) invert = true;
    if (start < 0) start += 360;
    if (end < 0) end += 360;
    if (end < start)
    {
        int temp = start;
        start = end;
        end = temp;
    }
    for (int i = start / 2; i <= end / 2; i++)
    {
        transform.GetChild(i).gameObject.SetActive(true);
    }
    if (invert)
    {
        foreach (Transform child in transform)
        {
            child.gameObject.SetActive(!child.gameObject.activeSelf);
        }
    }
}
```

6.5 Saving the Data

Saving the data is handled in two parts. The *SaveDataCSV* class is responsible for creating and appending a .csv file with the data points in it. The implementation of saving was based on the method by Sushanta Chakraborty [13], but we separated the saving into the string list and writing out to the stream, and the method appends existing files instead of overwriting them. In the inspector, we can set an ID and a comment for each file, and at initialization, if the file doesn't exist, it will be created in the format of result_Day-Month-Year_comment_id.csv. The AddDataToSaveBuffer method takes in a series of floats and a string, converts them into a string array, then adds the array to the rowData list. After this, the SaveFromBuffer method then copies each string array from rowData into a 2D string array, then joins each row with a string builder, with a comma as a delimiter. Finally, the method opens the previously created file and appends the strings in a new line. Each fruit has the *ItemToPlace* script attached to them. While a fruit is held, the script logs the tracker and HMD data until it is released. This is to make sure the data saved is at the point of release, not point of impact on the desk, at which point the users may have turned away. When the fruit collides with a surface using the "TargetPlatform" tag, it dies and calls the AddDataToSaveBuffer method with the trackers' and HMD's angles, the angle differences, the user's percieved rotation, the scaling factor and the direction they were looking at. On destruction, the scrip also calls the ShowMarkers method of the secondary angle marker managers, based on which side of the desk it was dropped on, to show the users the angle of their previous rotation for the next task.

6.6 Body Representation

The body representation is controlled partly by the *TestConditionManager* class. When the "Avatar" boolean is checked in the test condition manager, a 3D body appears at the position of the user, and hands appear at the position of the controllers. When it's unchecked, there is no body representation and instead of hands the user has tiny red spheres where the controllers' attach points are. The movements of the body are controlled by the *IKControl* class using Unity's built in Inverse Kinematics methods. The body has a full humanoid rig, and an animation controller with a default standing animation, with the IK pass checked. The upper body's position and the low back's rotation is controlled by the tracker on the user's hip, while the legs use the inverse kinematic methods, with the feet attached to two objects on the ground in the middle of the desk.

6.7 Improvements and Technical Issues

There were two technical issues regarding the prototype, one of them was that with the scaling enabled, if the user looked over 180 degrees behind them, the scene jumped. This was due to the implementation, where any rotation is over 180 degrees, we subtract 360 from them to get a signed rotation between -180 and 180. This way e.g. a 10% rotation would jump from 198 degrees of perceived rotation to -198 degrees.

The second was a jitter of the controllers when the scaling was enabled, and a jitter of the entire screen on wireless VR, even when the game ran at over 200 frames per second. This is most likely due to the fact that the rotation and position of the scene is calculated and set on the same frame, every frame, based on the HMD's position and rotation.

Besides fixing the technical issues, two improvements could be made to the program. The first would be rewriting the core using the singleton pattern, where one game manager singleton would be responsible for the game properties, because currently the game has a lot of dependencies and isn't very scaleable. The second would be rewriting the method for scaling the rotations. The current way it's implemented modifies the position of every object, and so when using fast movements, physics calculations are slow. Using the method with a secondary camera and rendering the image to the HMD seems like the preferable solution, as it would not require constantly repositioning either a parent object of the HMD or the scene, and it could provide a solution to the jittering issue.

7. Movement experiment

7.1 Script

To make sure that every participant starts in the same condition and with the same knowledge, a script has been written to explain the various tasks, elements, and exercises that they will perform. This script was read aloud to all participants while they were inside the virtual environment, so they could familiarize themselves with the topics being explained to them.

> "Welcome, thanks for participating in our experiment. First and foremost, we would like to make sure that you know that we are testing the system and not you.
>
> We will ask you to perform a movement under different circumstances, and we will measure the angle of this movement. We have developed a game in which you sort fruit in front of you. We would like you to move the apples to one side and the oranges to another: this will be indicated in the bowl in front of you when you start the game. You pick up the fruit with the trigger.
>
> The movement in question is a spine rotation, and while performing the movement we want you to not move your feet. We would like you to pick up the apples with your right hand and move them to the left, and pick up the oranges with the left hand and move them to the right. You do not have to place the fruit, you can just drop them. We want you to move as far as you can without hurting, and when you reach this position you just drop the fruit onto the circular table.
>
> When you move you will see some spheres change and follow you: these spheres represent the difference between the tracker on your hip and between your shoulder blades. The more spheres appear the more you have rotated, which will increase the score shown on the monitor. When you have completed a movement you will see some other sphere. These spheres represent the last rotation you made."

7.2 Questionnaires

The VRSQ questionnaires for this experiment were designed to reveal if any virtual reality sickness was induced by the solution. In order to minimize the time used on questionnaires, since answers were needed before and after every condition (in theory resulting in eight questionnaires), some changes were made to this procedure. First, it was decided that the post-test of the previous condition, would serve as the pre-test of the following condition. Second, it was decided that only the very first and the very last VRSQ questionnaires would be answered on a Likert-scale, while the rest would answered binary, only noting down if a symptom was present or not present.

It was decided that this procedure was viable, as any present simulator sickness (and the extent of which) would be revealed by the full pre- and post-test, and the questionnaires in between would only serve to identify where the cause of the simulator sickness was, and for this the full point system was not necessary - it was enough to simply see how many symptoms were present.

The body perception questionnaire and the game design questionnaire was designed by the group, with no references to other similar questionnaires.

Rotational Movement Experiment

1. **Number**

____

Virtual Reality Sickness Questionnaire

Select how much each symptom below is affecting you right now

2. **General discomfort**

Mark only one oval.

- ⬭ None
- ⬭ Slight
- ⬭ Moderate
- ⬭ Severe

3. **Fatigue**

Mark only one oval.

- ⬭ None
- ⬭ Slight
- ⬭ Moderate
- ⬭ Severe

4. **Eye strain**

Mark only one oval.

- ⬭ None
- ⬭ Slight
- ⬭ Moderate
- ⬭ Severe

5. **Difficulty focusing**

Mark only one oval.

- ⬭ None
- ⬭ Slight
- ⬭ Moderate
- ⬭ Severe

6. **Headache**

Mark only one oval.

- None
- Slight
- Moderate
- Severe

7. **Fullness of the Head**

Mark only one oval.

- None
- Slight
- Moderate
- Severe

8. **Blurred vision**

Mark only one oval.

- None
- Slight
- Moderate
- Severe

9. **Dizziness with eyes closed**

Mark only one oval.

- None
- Slight
- Moderate
- Severe

10. **Vertigo (loss of orientation with respect to vertical upright)**

Mark only one oval.

- None
- Slight
- Moderate
- Severe

37. **Vertigo (loss of orientation with respect to vertical upright)**

Mark only one oval.

- Not present
- Present

Body Perception

Rate your experiences during the four conditions. Please, do not use the same number twice.

47. **Rate the four conditions from best (1) to worst (4) based on which felt most natural.**

Mark only one oval per row.

	1	2	3	4
First condition	◯	◯	◯	◯
Second condition	◯	◯	◯	◯
Third condition	◯	◯	◯	◯
Fourth condition	◯	◯	◯	◯

48. **Rate the four conditions from best (1) to worst (4) based on which best represented your actual movement.**

Mark only one oval per row.

	1	2	3	4
First condition	◯	◯	◯	◯
Second condition	◯	◯	◯	◯
Third condition	◯	◯	◯	◯
Fourth condition	◯	◯	◯	◯

49. **Rate the four conditions from best (1) to worst (4) based on which best represented your body.**

Mark only one oval per row.

	1	2	3	4
First condition	◯	◯	◯	◯
Second condition	◯	◯	◯	◯
Third condition	◯	◯	◯	◯
Fourth condition	◯	◯	◯	◯

Game Design

Rate the various game design elements implemented.

50. **How useful did you find the arc representing your spine rotation?**

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not useful at all	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Very useful

51. **How useful did you find the score above arc?**

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not useful at all	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Very useful

52. **How useful did you find the total score on the PC?**

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not useful at all	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Very useful

7.3 Raw results

The raw results can be found in the 96 .CSV files in appendix, in addition to the full results of the body perception and game design questionnaires C.

7.3.1 Baseline

	Average						Rank of Average					
	Ctr	Trt1	Trt2	Trt3	Trt4	Trt5	Ctr (Rank)	Trt1 (Rank)	Trt2 (Rank)	Trt3 (Rank)	Trt4 (Rank)	Trt5 (Rank)
Participant 1	27.07	22.20	20.35	29.21	22.53	29.86	3	5	6	2	4	1
Participant 2	43.98	43.47	43.77	44.04	46.82	49.95	4	6	5	3	2	1
Participant 3	24.41	29.75	23.51	23.71	25.56	23.65	3	1	6	4	2	5
Participant 4	41.03	43.99	45.42	42.42	41.20	41.70	6	2	1	3	5	4
Participant 5	31.55	35.93	35.63	38.24	37.48	37.93	6	4	5	1	3	2
Participant 6	16.92	16.07	18.71	17.34	16.81	19.38	4	6	2	3	5	1
Participant 7	36.14	44.60	45.54	41.33	36.27	39.00	6	2	1	3	5	4
Participant 8	18.67	21.79	18.65	21.59	19.79	16.36	4	1	5	2	3	6
Participant 9	27.98	26.49	19.53	24.72	15.65	30.63	2	3	5	4	6	1
Participant 10	27.13	30.36	34.80	37.11	41.71	41.39	6	5	4	3	1	2
Participant 11	41.56	42.74	42.07	41.68	41.30	42.23	5	1	3	4	6	2
Participant 12	36.25	31.15	31.35	33.50	35.09	32.34	1	6	5	3	2	4
Participant 13	32.99	31.24	31.78	34.14	31.51	31.59	2	6	3	1	5	4
Participant 14	25.56	26.09	26.39	29.07	28.55	27.24	6	5	4	1	2	3
Participant 15	31.39	32.90	34.95	36.99	35.06	31.77	6	4	3	1	2	5
Participant 16	42.05	43.72	43.31	44.53	44.11	44.66	6	4	5	2	3	1
Participant 17	33.39	32.30	35.80	33.35	29.62	28.80	2	4	1	3	5	6
Participant 18	17.78	19.02	20.55	19.11	18.68	16.54	5	3	1	2	4	6
Participant 19	22.77	23.19	24.87	23.11	22.42	23.05	5	2	1	3	6	4
Participant 20	27.65	32.59	33.75	34.91	33.90	35.25	6	5	4	2	3	1
Participant 21	37.08	37.94	39.14	38.75	41.21	33.30	5	4	2	3	1	6
Participant 22	49.10	44.89	44.56	45.79	40.29	45.22	1	4	5	2	6	3
Participant 23	40.68	29.66	42.42	39.14	41.62	51.09	4	6	2	5	3	1
Participant 24	30.79	29.81	30.74	32.16	29.44	30.22	2	5	3	1	6	4

Figure 7.1: The means of the hip-back rotation for every set of four motions in the baseline condition.

The data seen on Figure 7.1 is the dataset used to calculate the statistical difference between treatments of the hip-back rotations. Every number in the "Average" columns are a mean of four motions performed under the same treatment. The data on Figure 7.2 shows the rotation of the hip, but has otherwise undergone the same calculations. Both tables show the degrees of rotation.

	Average						Rank of Average					
	Ctr	Trt1	Trt2	Trt3	Trt4	Trt5	Ctr (Rank)	Trt1 (Rank)	Trt2 (Rank)	Trt3 (Rank)	Trt4 (Rank)	Trt5 (Rank)
Participant 1	50.05	52.75	48.48	58.19	55.12	63.59	5	4	6	2	3	1
Participant 2	52.77	53.87	48.60	52.96	54.71	54.69	5	3	6	4	1	2
Participant 3	69.53	65.50	65.29	70.15	62.15	60.97	2	3	4	1	5	6
Participant 4		101.16	82.39	89.72				1	3	2		
Participant 5	55.11	57.39	63.73	57.71	53.85	46.57	4	3	1	2	5	6
Participant 6	33.04	30.27	31.73	30.06	30.87	30.93	1	5	2	6	4	3
Participant 7	61.96	73.06	41.08	47.74	46.68	41.45	2	1	6	3	4	5
Participant 8	45.31	47.96	45.84	42.47	45.74	35.91	4	1	2	5	3	6
Participant 9	67.09	68.85	75.85	81.69		88.11	5	4	3	2		1
Participant 10	49.70	56.49	57.49	61.10	62.66	61.40	6	5	4	3	1	2
Participant 11	28.04	42.41	23.12	36.87	52.31	47.86	5	3	6	4	1	2
Participant 12	9.12	9.37	5.69	13.70		8.24	3	2	5	1		4
Participant 13	44.94	47.00	52.05	51.44	54.23	51.03	6	5	2	3	1	4
Participant 14	31.49	33.40	26.97	15.26		9.52	2	1	3	4		5
Participant 15	26.89	31.60	33.45	32.49	40.51	32.65	6	5	2	4	1	3
Participant 16	40.32	42.84	41.37	53.09	55.90	39.98	5	3	4	2	1	6
Participant 17	23.48	26.51	28.01	30.47	32.20	23.83	6	4	3	2	1	5
Participant 18	53.34	48.08	51.06	50.89	57.84	56.04	3	6	4	5	1	2
Participant 19	42.49	47.63	50.26	48.17	48.07	49.29	6	5	1	3	4	2
Participant 20	26.59	27.87	37.92	37.62	31.95	44.98	6	5	2	3	4	1
Participant 21	66.16	62.71	70.01	64.83	66.06	67.53	3	6	1	5	4	2
Participant 22	79.66	77.63	72.74	76.37	65.25	71.90	1	2	4	3	6	5
Participant 23	44.69	29.42	38.68	45.88	49.89	54.26	4	6	5	3	2	1
Participant 24	54.75	56.50	54.51	62.46	57.29	58.62	5	4	6	1	3	2

Figure 7.2: The means of the hip rotation for every set of four motions in the baseline condition.

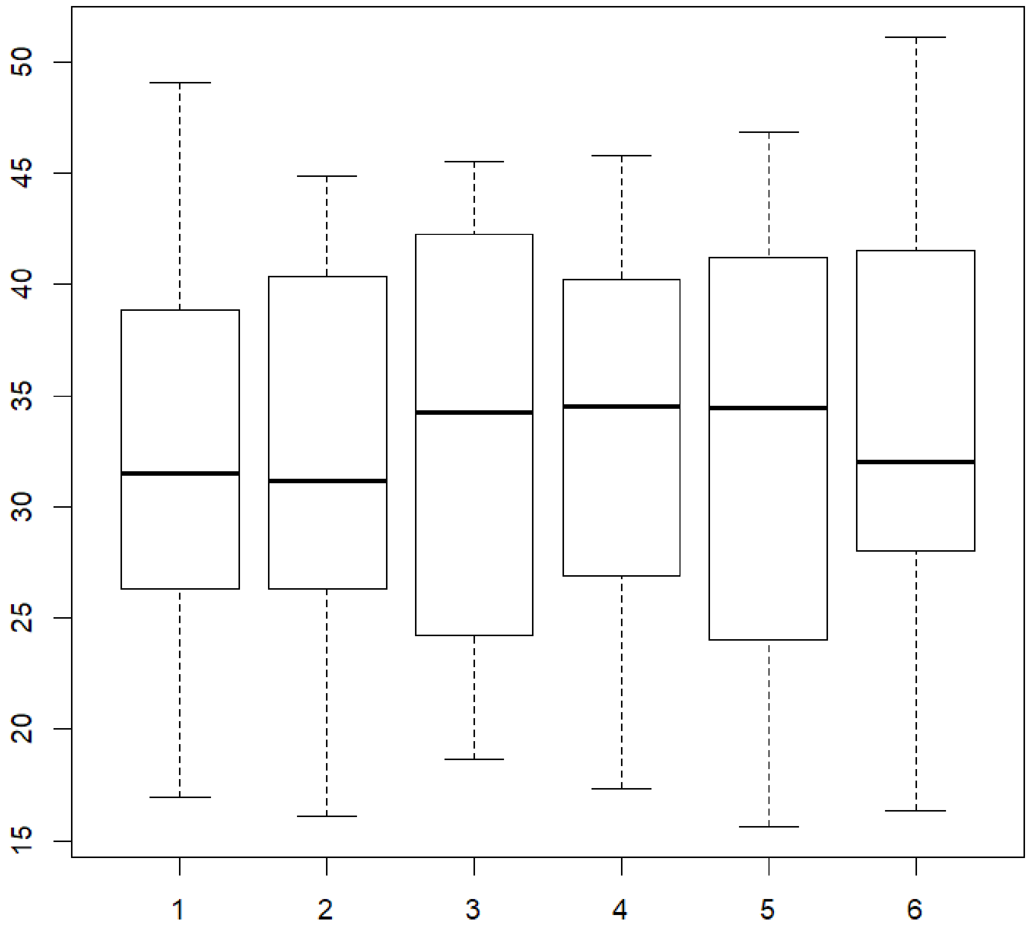

Figure 7.3: The baseline hip-back rotation plotted in a boxplot.

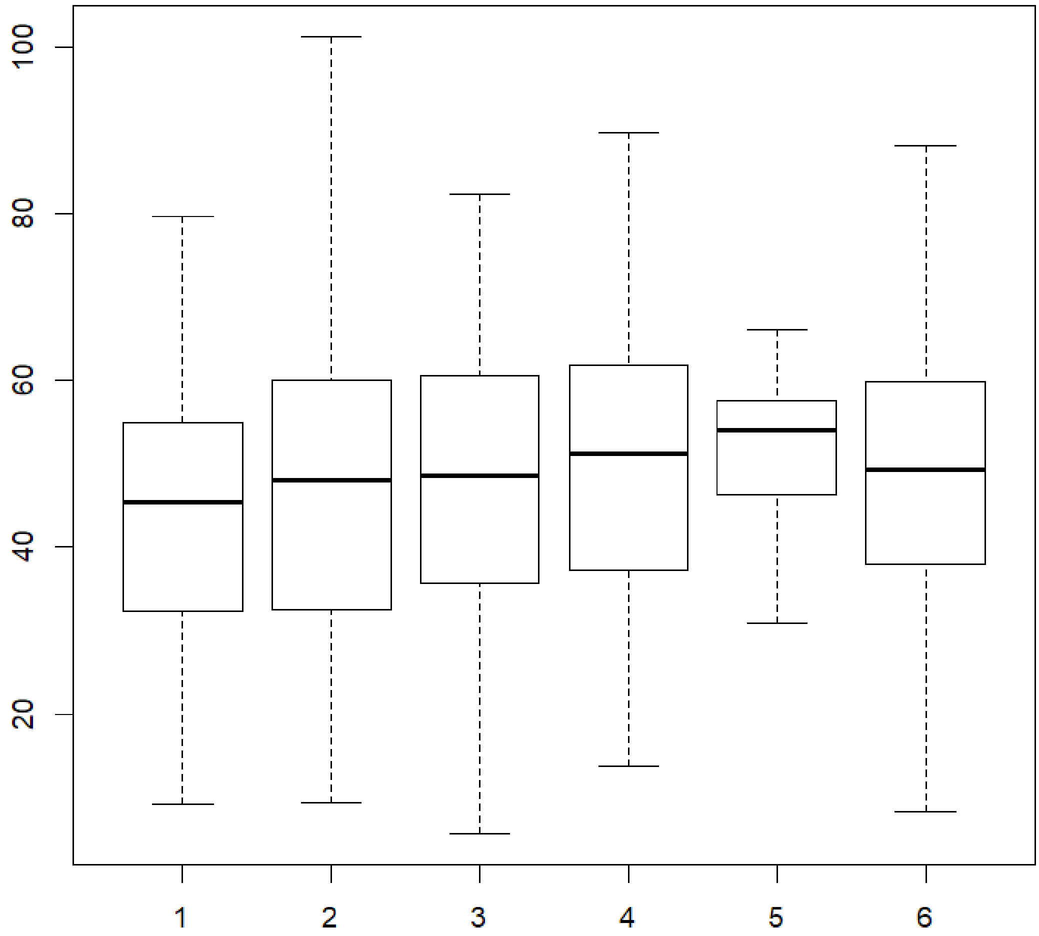

Figure 7.4: The baseline hip rotation plotted in a boxplot.

Figure 7.3 and Figure 7.4 show the hip-back and hip-rotations between treatments plotted in boxplots. These were used to identify and remove outliers in the datasets. It can also be seen how alot of the data overlap indicating no significant difference between the treatments.

Still it was necessary to perform a Variance of Variance test to statistically show these results. These tests make assumption about the so it was necessary to know if the data was collected through repeated measures, and was parametric or non-parametric. To know if the data was normally distributed the Shapiro-Wilks test was used. The results of the analysis of the hip-back rotation can be seen on Figure 7.5a and the hip rotation can be seen on Figure 7.5b.

The results of the ANOVA on the hip-back can be seen Figure 7.6, while the results of the ANOVA test on the hip rotation can be seen on Figure 7.7.

```
        Shapiro-Wilk normality test

data:  as.matrix(baselineHipBackData)
W = 0.96856, p-value = 0.002151
```

(a) The results of the Shapiro-Wilks test for the baseline hip-back rotation.

```
        Shapiro-Wilk normality test

data:  as.matrix(baselineHipData)
W = 0.982, p-value = 0.1091
```

(b) The results of the Shapiro-Wilks test for the baseline hip rotation.

Figure 7.5

```
        Friedman rank sum test

data:  as.matrix(baselineHipBackData)
Friedman chi-squared = 11.595, df = 5, p-value = 0.04078
```

(a)

```
Multiple comparisons between groups after Friedman test
p.value: 0.05
Comparisons
    obs.dif critical.dif difference
1-2       6     38.04453      FALSE
1-3      18     38.04453      FALSE
1-4      39     38.04453       TRUE
1-5      10     38.04453      FALSE
1-6      23     38.04453      FALSE
2-3      12     38.04453      FALSE
2-4      33     38.04453      FALSE
2-5       4     38.04453      FALSE
2-6      17     38.04453      FALSE
3-4      21     38.04453      FALSE
3-5       8     38.04453      FALSE
3-6       5     38.04453      FALSE
4-5      29     38.04453      FALSE
4-6      16     38.04453      FALSE
5-6      13     38.04453      FALSE
```

(b) .

Figure 7.6: The results of the ANOVA test for the baseline hip-back rotation.

```
              Df Sum Sq Mean Sq F value Pr(>F)
ind            5    431   86.25   0.273  0.927
Residuals    132  41636  315.42
6 observations deleted due to missingness
```

Figure 7.7: The results of the ANOVA test for the baseline hip rotation.

7.3.2 Only-avatar

	Average						Rank of Average					
	Ctr	Trt1	Trt2	Trt3	Trt4	Trt5	Ctr (Rank)	Trt1 (Rank)	Trt2 (Rank)	Trt3 (Rank)	Trt4 (Rank)	Trt5 (Rank)
Participant 1	24.26	21.68	22.87	25.63	22.43	25.22	3	6	4	1	5	2
Participant 2	38.28	34.10	47.77	45.41	52.68	47.17	5	6	2	4	1	3
Participant 3	25.48	24.87	13.03	27.20	25.45	25.62	3	5	6	1	4	2
Participant 4	44.56	37.69	40.24	46.00	45.31	46.19	4	6	5	2	3	1
Participant 5	26.19	21.97	22.32	23.39	23.80	29.96	2	6	5	4	3	1
Participant 6	18.16	19.03	19.28	18.33	20.05	22.20	6	4	3	5	2	1
Participant 7	30.70	33.36	47.65	43.41	50.66		5	4	2	3	1	
Participant 8	18.15	18.70	14.97	17.59	15.62	18.55	3	1	6	4	5	2
Participant 9	24.63	27.37	12.18	27.79	32.69	31.65	5	4	6	3	1	2
Participant 10	38.97	38.77	35.85	39.70	27.24	25.97	2	3	4	1	5	6
Participant 11	37.42	38.69	38.60	38.23	38.06	32.58	5	1	2	3	4	6
Participant 12	33.82	28.19	19.98	30.87	29.91	29.08	1	5	6	2	3	4
Participant 13	31.43	30.71	31.45	29.54	31.65	30.95	3	5	2	6	1	4
Participant 14	30.77	22.31	26.17	22.91	24.48	28.55	1	6	3	5	4	2
Participant 15	31.68	32.50	32.14	32.27	32.64		5	2	4	3	1	
Participant 16	42.75	42.61	42.90	46.27	42.73	41.96	3	5	2	1	4	6
Participant 17	29.31	31.31	30.40	29.84	28.66	29.45	5	1	2	3	6	4
Participant 18	18.69	10.36	16.80	13.26	19.38	20.28	3	6	4	5	2	1
Participant 19	21.28	24.83	26.08	22.42	12.77	25.67	5	3	1	4	6	2
Participant 20	37.19	37.40	37.20	35.49	35.24	33.08	3	1	2	4	5	6
Participant 21	35.57	38.16	38.64	38.14	37.26	35.84	6	2	1	3	4	5
Participant 22	41.38	39.86	40.59	39.75	40.43	45.02	2	5	3	6	4	1
Participant 23	47.93	50.49	47.50	46.42	48.26	47.46	3	1	4	6	2	5
Participant 24	32.10	33.31	32.97	34.22	38.24	33.41	6	4	5	2	1	3

Figure 7.8: The means of the hip-back rotation for every set of four motions in the only-avatar condition.

The data seen on Figure 7.8 is the dataset used to calculate the statistical difference between treatments of the hip-back rotations. Every number in the "Average" columns are a mean of four motions performed under the same treatment. The data on Figure 7.9 shows the rotation of the hip, but has otherwise undergone the same calculations. Both tables show the degrees of rotation.

	Average						Rank of Average					
	Ctr	Trt1	Trt2	Trt3	Trt4	Trt5	Ctr (Rank)	Trt1 (Rank)	Trt2 (Rank)	Trt3 (Rank)	Trt4 (Rank)	Trt5 (Rank)
Participant 1	51.51	44.14	50.63	47.04	46.98	43.77	1	5	2	3	4	6
Participant 2	33.23	40.36	36.85	47.70	47.48	49.74	6	4	5	2	3	1
Participant 3	62.54	63.59	43.98	65.65	64.20	56.21	4	3	6	1	2	5
Participant 4	85.78	69.80	73.41	80.18	82.12	71.28	1	6	4	3	2	5
Participant 5	47.25	54.93	51.76	41.79	58.03	40.81	4	2	3	5	1	6
Participant 6	37.01	40.02	45.33	45.33	41.52	41.32	6	5	1	2	3	4
Participant 7	64.47	64.41	81.92	73.55	72.74		4	5	1	2	3	
Participant 8	53.71	59.85	59.21	52.56	51.95	51.21	3	1	2	4	5	6
Participant 9	61.72	66.57	8.39	56.46	66.23	63.06	4	1	6	5	2	3
Participant 10	56.46	58.85	57.93	56.49	41.50	39.70	4	1	2	3	5	6
Participant 11		16.83		27.36	37.13	33.11		4		3	1	2
Participant 12		2.97		5.83	5.38			3		1	2	
Participant 13	50.15	54.29	54.97	57.27	59.55	61.76	6	5	4	3	2	1
Participant 14	39.92	34.67	38.74	44.93	34.24	25.29	2	4	3	1	5	6
Participant 15	46.63	48.46	37.29	36.91	40.87		2	1	4	5	3	
Participant 16	20.86	22.36	32.53	39.61	45.37	48.95	6	5	4	3	2	1
Participant 17	29.63	33.50	36.85	35.40	37.00	34.36	6	5	2	3	1	4
Participant 18	57.14	36.96	59.85	34.92	58.43	58.82	4	5	1	6	3	2
Participant 19	44.55	53.25	54.61	51.09	25.70	52.33	5	2	1	4	6	3
Participant 20	42.54	50.67	14.83	27.31	14.70	27.94	2	1	5	4	6	3
Participant 21	66.70	66.30	59.93	64.06	63.36	58.75	1	2	5	3	4	6
Participant 22	74.37	78.70	80.58	77.90	78.76	76.28	6	3	1	4	2	5
Participant 23	57.54	64.89	58.09	59.38	60.67	60.65	6	1	5	4	2	3
Participant 24	60.36	60.34	64.77	65.36	57.66	58.88	3	4	2	1	6	5

Figure 7.9: The means of the hip rotation for every set of four motions in the only-avatar condition.

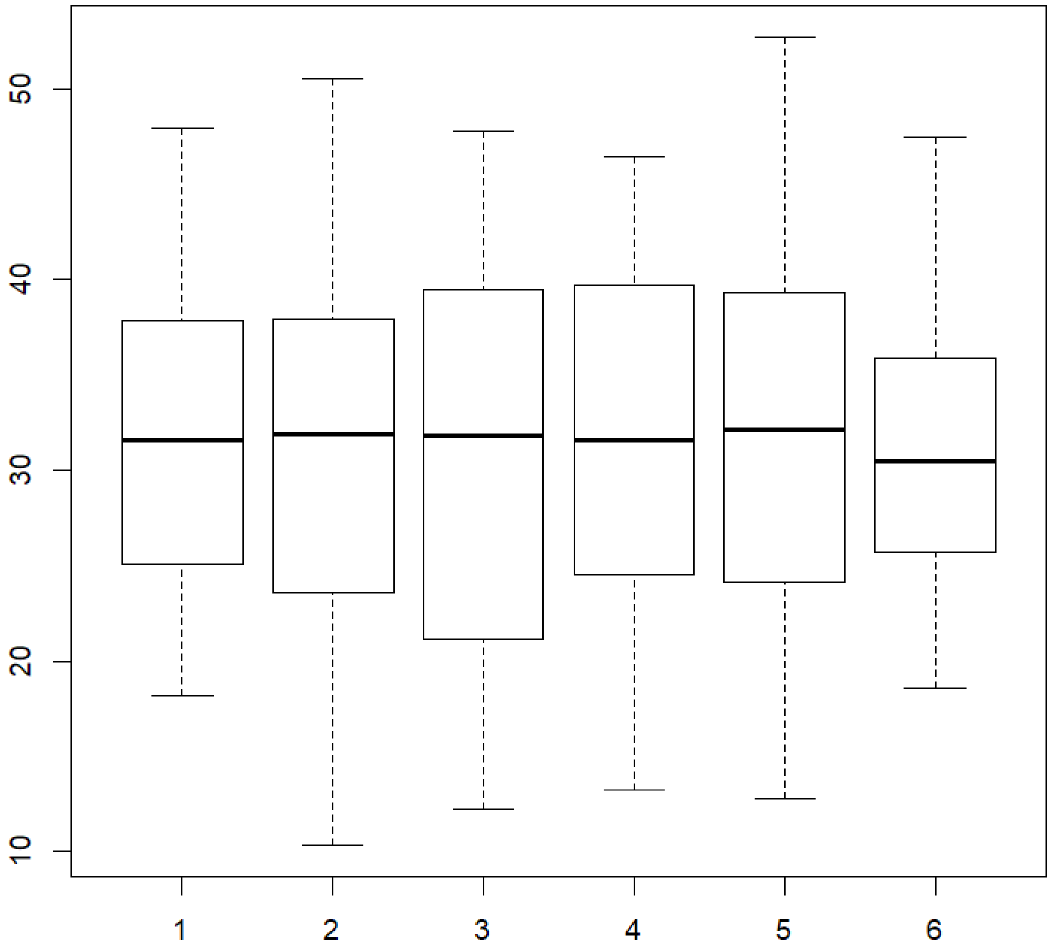

Figure 7.10: The only-avatar hip-back rotation plotted in a boxplot.

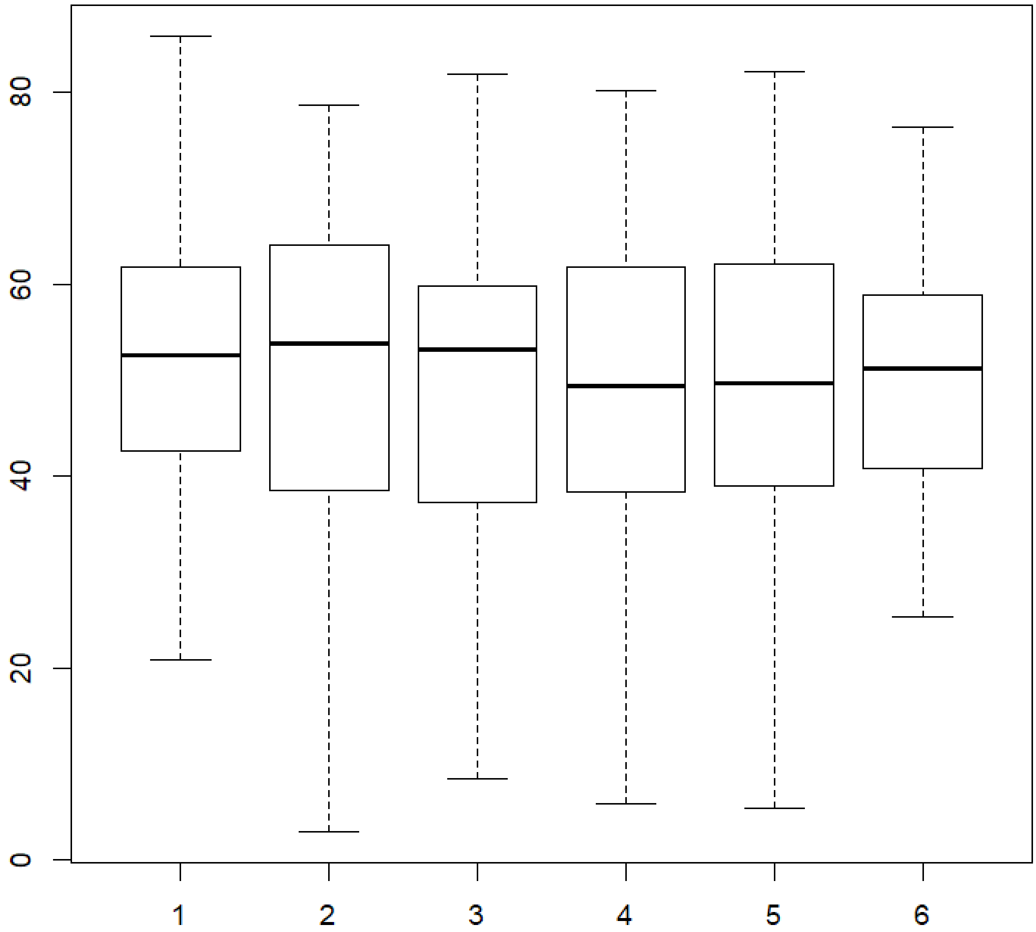

Figure 7.11: The only-avatar hip rotation plotted in a boxplot.

Figure 7.10 and Figure 7.11 show the hip-back and hip-rotations between treatments plotted in boxplots. These were used to identify and remove outliers in the datasets. It can also be seen how alot of the data overlap indicating no significant difference between the treatments.

Still it was necessary to perform a Variance of Variance test to statistically show these results. These tests make assumption about the so it was necessary to know if the data was collected through repeated measures, and was parametric or non-parametric. To know if the data was normally distributed the Shapiro-Wilks test was used. The results of the analysis of the hip-back rotation can be seen on Figure 7.12a and the hip rotation can be seen on Figure 7.12b.

The results of the ANOVA on the hip-back can be seen Figure 7.13, while the results of the ANOVA test on the hip rotation can be seen on Figure 7.14.

```
        Shapiro-Wilk normality test

data:  as.matrix(avatarHipBackData)
W = 0.98393, p-value = 0.1224
```

(a) The results of the Shapiro-Wilks test for the only-avatar hip-back rotation.

```
        Shapiro-Wilk normality test

data:  as.matrix(avatarHipData)
W = 0.98764, p-value = 0.349
```

(b) The results of the Shapiro-Wilks test for the only-avatar hip rotation.

Figure 7.12

```
             Df Sum Sq Mean Sq F value Pr(>F)
ind           5     63   12.56   0.131  0.985
Residuals   136  13034   95.84
2 observations deleted due to missingness
```

Figure 7.13: The results of the ANOVA test for the only-avatar hip-back rotation.

```
             Df Sum Sq Mean Sq F value Pr(>F)
ind           5     97   19.46   0.066  0.997
Residuals   131  38438  293.42
7 observations deleted due to missingness
```

Figure 7.14: The results of the ANOVA test for the only-avatar hip rotation.

7.3.3 Scaling

	Average						Rank of Average					
	Ctr	Trt1	Trt2	Trt3	Trt4	Trt5	Ctr (Rank)	Trt1 (Rank)	Trt2 (Rank)	Trt3 (Rank)	Trt4 (Rank)	Trt5 (Rank)
Participant 1	21.08	24.08	26.19	26.64	25.97	28.40		5	3	2	4	1
Participant 2	44.93	45.68	49.84	41.08	48.17	45.43	5	3	1	6	2	4
Participant 3	27.06	25.92	28.26	24.16	28.37	31.58	4	5	3	6	2	1
Participant 4	46.62	40.61	36.83	43.63	37.94	36.88	1	3	6	2	4	5
Participant 5	30.45	32.91	36.66	35.19	37.00	35.45	6	5	2	4	1	3
Participant 6	17.45	14.18	16.39	19.26	17.96	17.43	3	6	5	1	2	4
Participant 7	26.69	31.32	33.71	33.90	32.31	33.34	6	5	2	1	4	3
Participant 8	20.51	20.14	22.81	19.20	18.18	19.44	2	3	1	5	6	4
Participant 9	21.74	22.72	26.18	26.80	26.03	31.92	6	5	3	2	4	1
Participant 10	38.08	39.31	40.91	41.39	41.30	42.20	6	5	4	2	3	1
Participant 11	37.54	35.75	30.51	36.47	37.04	40.02	2	5	6	4	3	1
Participant 12	29.52	30.01	28.72	27.19	31.60	25.61	3	2	4	5	1	6
Participant 13	31.68	33.64	32.86	30.74	30.66	32.04	4	1	2	5	6	3
Participant 14	27.57	21.45	23.16	26.27	27.58	27.88	3	6	5	4	2	1
Participant 15	34.21	33.74	33.87	32.16	32.31	33.34	1	3	2	6	5	4
Participant 16	49.93	49.04	46.90	47.93	45.04	45.86	1	2	4	3	6	5
Participant 17	29.69	29.30	31.88	28.44	30.89	30.32	4	5	1	6	2	3
Participant 18	18.35	19.81	25.18	25.30	21.93	24.35	6	5	2	1	4	3
Participant 19	20.53	21.87	24.71	25.05	26.69	26.00	6	5	4	3	1	2
Participant 20	29.29	39.96	37.63	36.99	37.78	38.71	6	1	4	5	3	2
Participant 21	36.31	37.97	34.01	38.82	37.51		4	2	5	1	3	
Participant 22	41.96	39.52	44.90	37.12	34.34	44.96	3	4	2	5	6	1
Participant 23	47.41	44.04	49.61	48.94	52.31	53.92	5	6	3	4	2	1
Participant 24	32.59	30.61	29.58	28.41	28.56	29.56	1	2	3	6	5	4

Figure 7.15: The means of the hip-back rotation for every set of four motions in the only-scaling condition.

The data seen on Figure 7.15 is the dataset used to calculate the statistical difference between treatments of the hip-back rotations. Every number in the "Average" columns are a mean of four motions performed under the same treatment. The data on Figure 7.16 shows the rotation of the hip, but has otherwise undergone the same calculations. Both tables show the degrees of rotation.

	Average						Rank of Average					
	Ctr	Trt1	Trt2	Trt3	Trt4	Trt5	Ctr (Rank)	Trt1 (Rank)	Trt2 (Rank)	Trt3 (Rank)	Trt4 (Rank)	Trt5 (Rank)
Participant 1	46.04	45.87	47.46	45.62	46.80	49.38	4	5	2	6	3	1
Participant 2	40.87	40.48	35.44	49.58	48.66	45.91	4	5	6	1	2	3
Participant 3	70.41	75.34	74.60	76.00	66.86	65.09	4	2	3	1	5	6
Participant 4	82.71	88.20	89.84	90.23	94.22	94.42	6	5	4	3	2	1
Participant 5	47.07	55.61	57.06	55.58	54.38	57.23	6	3	2	4	5	1
Participant 6	30.13	30.03	31.04	31.30	30.38	34.06	5	6	3	2	4	1
Participant 7	60.89	68.12	64.76	68.24	67.57	70.57	6	3	5	2	4	1
Participant 8	42.23	40.18	39.70	36.96	41.72	38.92	1	3	4	6	2	5
Participant 9	49.35	50.36	64.57	65.31	65.31	61.85	6	5	3	2	1	4
Participant 10	72.66	63.17	70.98	77.29	81.31	73.20	4	6	5	2	1	3
Participant 11	7.45	42.06	19.36	22.91	34.30	25.44	6	1	5	4	2	3
Participant 12	11.55	10.22	12.75	20.26	10.85	33.26	4	6	3	2	5	1
Participant 13	42.36	41.13	43.59	46.75	49.63	45.63	5	6	4	2	1	3
Participant 14	37.90	40.03	42.23	19.00	13.02	21.79	3	2	1	5	6	4
Participant 15	31.43	40.14	37.03	36.38	37.87	37.22	6	1	4	5	2	3
Participant 16	20.77	44.08	48.47	34.94	24.01	20.49	5	2	1	3	4	6
Participant 17	25.44	28.80	32.70	34.72	35.21	30.41	6	5	3	2	1	4
Participant 18	52.48	56.50	53.33	55.76	59.11	56.96	6	3	5	4	1	2
Participant 19	44.71	49.19	46.52	43.77	45.81	47.07	5	1	3	6	4	2
Participant 20	21.88	45.89	50.02	54.36	57.62	62.92	6	5	4	3	2	1
Participant 21	54.05	64.70	63.43	62.69	72.81		5	2	3	4	1	
Participant 22	74.52	74.95	73.77	72.07	69.71	71.23	2	1	3	4	6	5
Participant 23	53.30	57.61	60.04	59.37	61.85	65.03	6	5	3	4	2	1
Participant 24	73.25	61.06	65.13	61.67	60.06	57.26	1	4	2	3	5	6

Figure 7.16: The means of the hip rotation for every set of four motions in the only-scaling condition.

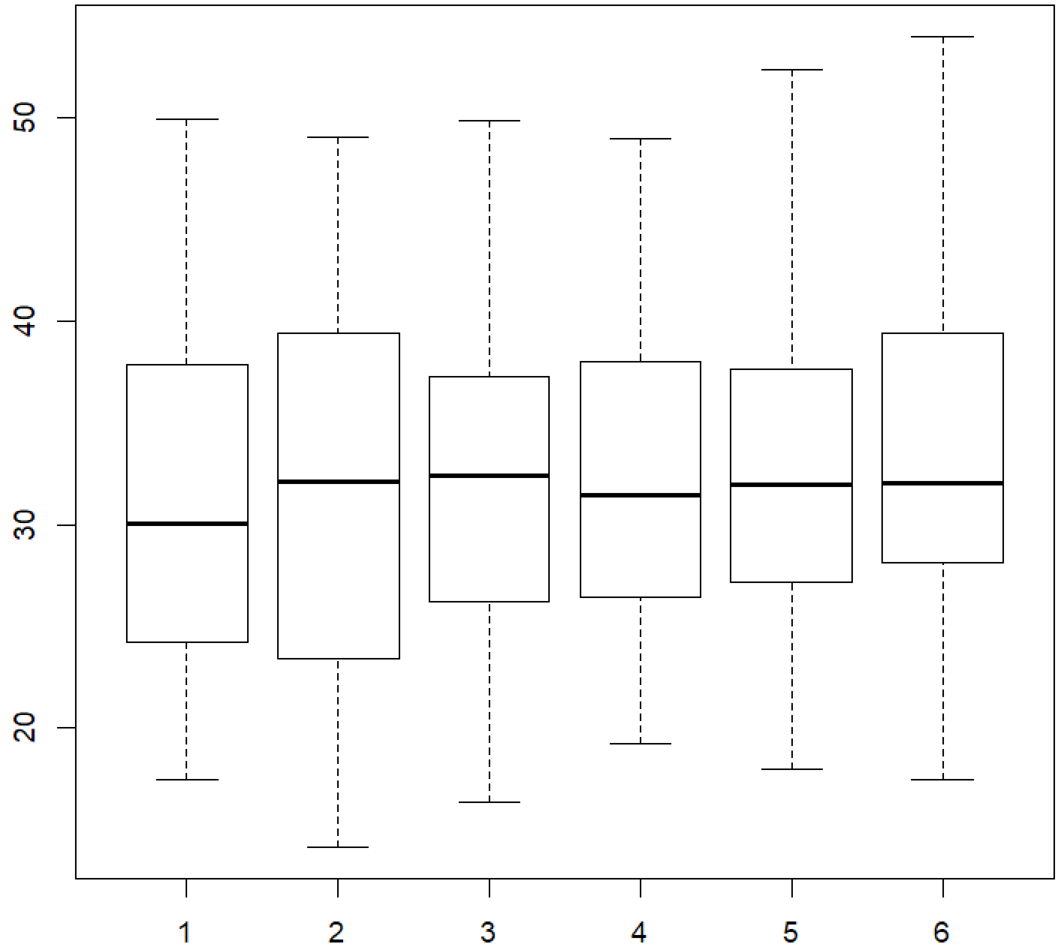

Figure 7.17: The only-scaling hip-back rotation plotted in a boxplot.

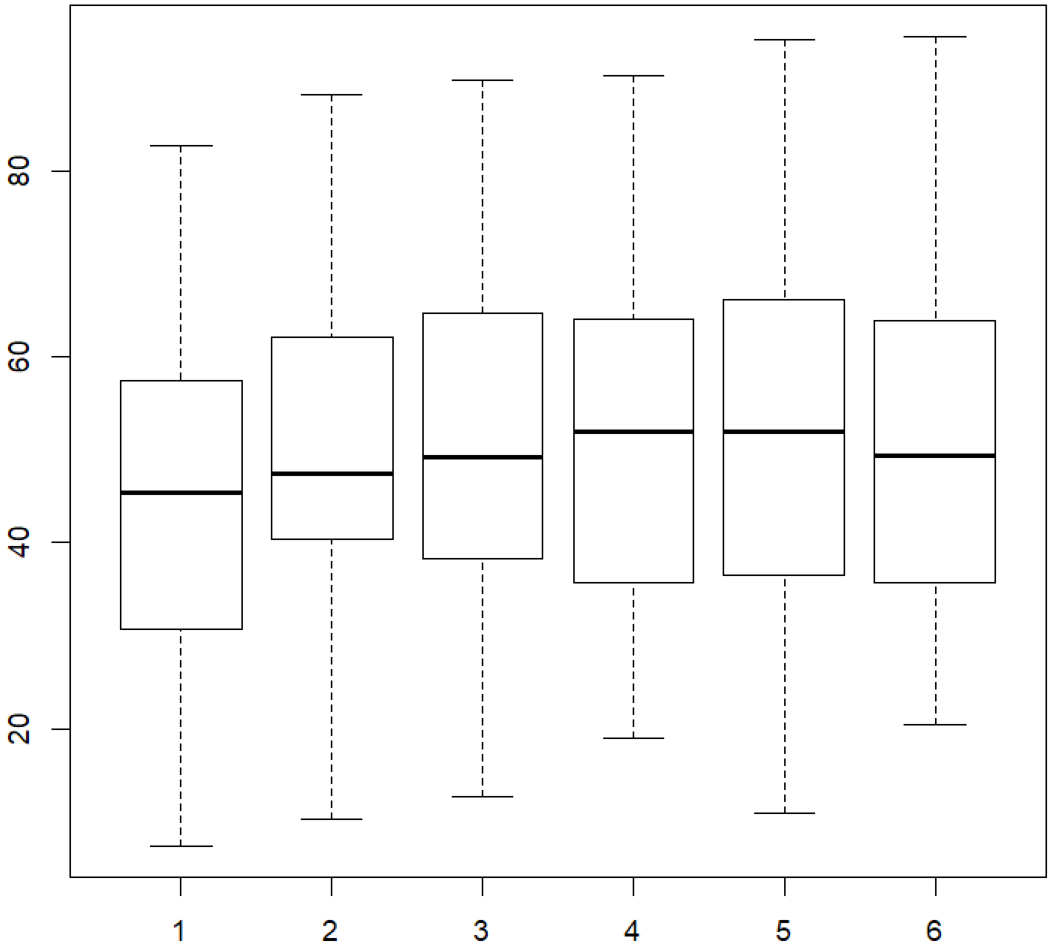

Figure 7.18: The only-scaling hip rotation plotted in a boxplot.

Figure 7.17 and Figure 7.18 show the hip-back and hip-rotations between treatments plotted in boxplots. These were used to identify and remove outliers in the datasets. It can also be seen how alot of the data overlap indicating no significant difference between the treatments.

Still it was necessary to perform a Variance of Variance test to statistically show these results. These tests make assumption about the so it was necessary to know if the data was collected through repeated measures, and was parametric or non-parametric. To know if the data was normally distributed the Shapiro-Wilks test was used. The results of the analysis of the hip-back rotation can be seen on Figure 7.19a and the hip rotation can be seen on Figure 7.19b.

The results of the ANOVA on the hip-back can be seen Figure 7.20, while the results of the ANOVA test on the hip rotation can be seen on Figure 7.21.

```
        Shapiro-Wilk normality test

data:  as.matrix(scalingHipBackData)
W = 0.9797, p-value = 0.03764
```

(a) The results of the Shapiro-Wilks test for the only-scaling hip-back rotation.

```
        Shapiro-Wilk normality test

data:  as.matrix(scalingHipData)
W = 0.99153, p-value = 0.577
```

(b) The results of the Shapiro-Wilks test for the only-scaling hip rotation.

Figure 7.19

```
        Friedman rank sum test

data:  as.matrix(scalingHipBackData)
Friedman chi-squared = 8.2422, df = 5, p-value = 0.1434
```

(a)

```
Multiple comparisons between groups after Friedman test
p.value: 0.05
Comparisons
    obs.dif critical.dif difference
1-2       0     38.04453      FALSE
1-3      17     38.04453      FALSE
1-4       5     38.04453      FALSE
1-5      13     38.04453      FALSE
1-6      31     38.04453      FALSE
2-3      17     38.04453      FALSE
2-4       5     38.04453      FALSE
2-5      13     38.04453      FALSE
2-6      31     38.04453      FALSE
3-4      12     38.04453      FALSE
3-5       4     38.04453      FALSE
3-6      14     38.04453      FALSE
4-5       8     38.04453      FALSE
4-6      26     38.04453      FALSE
5-6      18     38.04453      FALSE
```

(b) .

Figure 7.20: The results of the ANOVA test for the only-scaling hip-back rotation.

```
        Friedman rank sum test

data:  as.matrix(scalingHipData)
Friedman chi-squared = 12.886, df = 5, p-value = 0.02448
```

(a)

```
Multiple comparisons between groups after Friedman test
p.value: 0.05
Comparisons
    obs.dif critical.dif difference
1-2    25.0     38.04453      FALSE
1-3    31.0     38.04453      FALSE
1-4    32.5     38.04453      FALSE
1-5    40.5     38.04453       TRUE
1-6    45.0     38.04453       TRUE
2-3     6.0     38.04453      FALSE
2-4     7.5     38.04453      FALSE
2-5    15.5     38.04453      FALSE
2-6    20.0     38.04453      FALSE
3-4     1.5     38.04453      FALSE
3-5     9.5     38.04453      FALSE
3-6    14.0     38.04453      FALSE
4-5     8.0     38.04453      FALSE
4-6    12.5     38.04453      FALSE
5-6     4.5     38.04453      FALSE
```

(b) .

Figure 7.21: The results of the ANOVA test for the only-scaling hip rotation.

7.3.4 Both scaling and avatar

	Average						Rank of Average					
	Ctr	Trt1	Trt2	Trt3	Trt4	Trt5	Ctr (Rank)	Trt1 (Rank)	Trt2 (Rank)	Trt3 (Rank)	Trt4 (Rank)	Trt5 (Rank)
Participant 1	24.31	24.12	25.22	30.48	28.39	28.23	5	6	4	1	2	3
Participant 2	45.13	44.01	48.62	48.11	46.41	47.25	5	6	1	2	4	3
Participant 3	24.10	23.71	27.44	28.77	26.73	27.04	5	6	2	1	4	3
Participant 4	47.79	43.47	45.13	45.57	50.44	46.13	2	6	5	4	1	3
Participant 5	34.06	35.38	33.08	35.34	35.36	38.66	5	2	6	4	3	1
Participant 6	20.53	20.77	20.30	19.09	19.05	19.74	2	1	3	5	6	4
Participant 7	37.02	35.47	30.03	32.57	40.99	34.21	2	3	6	5	1	4
Participant 8	18.46	18.63	19.34	22.05	22.99	21.02	6	5	4	2	1	3
Participant 9	28.50	23.62	23.89	22.04	24.51	26.29	1	5	4	6	3	2
Participant 10	38.57	36.68	38.36	38.55	39.17	41.30	3	6	5	4	2	1
Participant 11	40.92	42.21	43.68	43.65	44.83	43.97	6	5	3	4	1	2
Participant 12	35.11	33.37	33.68	33.29	39.37	22.71	2	4	3	5	1	6
Participant 13	32.53	30.61	28.14	25.24	32.53	31.28	1	4	5	6	2	3
Participant 14	29.07	30.12	30.76	29.01	28.85	26.79	3	2	1	4	5	6
Participant 15	36.05	34.69		32.25	34.34	31.83	1	2		4	3	5
Participant 16	44.19	43.06	40.49	37.84	40.11	40.80	1	2	4	6	5	3
Participant 17	30.25	31.78	31.56	30.78	28.14	33.05	5	2	3	4	6	1
Participant 18	17.85	16.22	18.80	22.10	19.32	21.84	5	6	4	1	3	2
Participant 19	22.05	24.57	22.99	24.32	26.33	26.15	6	3	5	4	1	2
Participant 20	33.89	24.81	24.71	31.09	27.80	25.69	1	5	6	2	3	4
Participant 21	35.09	37.61	37.73	40.71	40.52	40.66	6	5	4	1	3	2
Participant 22	37.99	37.75	41.13	39.68	40.83	41.26	5	6	2	4	3	1
Participant 23	37.40	45.06	43.33	44.26	40.57	48.61	6	2	4	3	5	1
Participant 24	28.59	27.90	30.69	29.60	31.23	32.94	5	6	3	4	2	1

Figure 7.22: The means of the hip-back rotation for every set of four motions in the both scaling and avatar condition.

The data seen on Figure 7.22 is the dataset used to calculate the statistical difference between treatments of the hip-back rotations. Every number in the "Average" columns are a mean of four motions performed under the same treatment. The data on Figure 7.23 shows the rotation of the hip, but has otherwise undergone the same calculations. Both tables show the degrees of rotation.

	Average						Rank of Average					
	Ctr	Trt1	Trt2	Trt3	Trt4	Trt5	Ctr (Rank)	Trt1 (Rank)	Trt2 (Rank)	Trt3 (Rank)	Trt4 (Rank)	Trt5 (Rank)
Participant 1	43.39	43.58	42.08	44.60	43.39	44.98	5	3	6	2	4	1
Participant 2	28.66	25.15	27.98	36.76	43.58	45.03	4	6	5	3	2	1
Participant 3	72.59	75.18	71.17	70.60	70.87	73.98	3	1	4	6	5	2
Participant 4	90.69	109.91	104.41	103.59	96.07	101.55	6	1	2	3	5	4
Participant 5	57.10	58.29	57.85	57.46	60.59	63.33	6	3	4	5	2	1
Participant 6	40.21	41.40	27.43	38.46	36.21	34.70	2	1	6	3	4	5
Participant 7	27.74	41.31	53.77	56.39	46.31	52.03	6	5	2	1	4	3
Participant 8	33.15	30.68	35.80	40.43	37.11	38.31	5	6	4	1	3	2
Participant 9	73.45	73.16	77.06	52.53	55.47	54.71	2	3	1	6	4	5
Participant 10	62.40	64.06	65.95	70.63	70.89	74.69	6	5	4	3	2	1
Participant 11	45.48	53.00	55.34	51.35	51.78	48.45	6	2	1	4	3	5
Participant 12	18.95	15.93	13.77	19.90	8.73	2.87	2	3	4	1	5	6
Participant 13	61.20	61.16	58.99	58.20	54.32	46.20	1	2	3	4	5	6
Participant 14	26.27	25.67	30.98	42.28	54.44	34.80	5	6	4	2	1	3
Participant 15	28.54	36.03		41.16	35.05	42.46	5	3		2	4	1
Participant 16	14.09	23.51	23.61	16.64	20.27	18.43	6	2	1	5	3	4
Participant 17	31.86	24.75	23.97	21.58	22.48	29.14	1	3	4	6	5	2
Participant 18	50.15	53.03	56.40	61.07	65.57	61.78	6	5	4	3	1	2
Participant 19	51.84	49.73	51.16	51.83	53.99	52.68	3	6	5	4	1	2
Participant 20	12.77	17.19	12.98	20.86	47.39	44.13	6	4	5	3	1	2
Participant 21	56.61	60.07	62.89	65.52	68.91	71.54	6	5	4	3	2	1
Participant 22	66.30	71.74	73.72	79.02	72.78	73.12	6	5	2	1	4	3
Participant 23	32.07	34.28	34.88	46.09	46.89	51.81	6	5	4	3	2	1
Participant 24	54.87	59.13	59.48	62.16	63.84	80.95	6	5	4	3	2	1

Figure 7.23: The means of the hip rotation for every set of four motions in the both scaling and avatar condition.

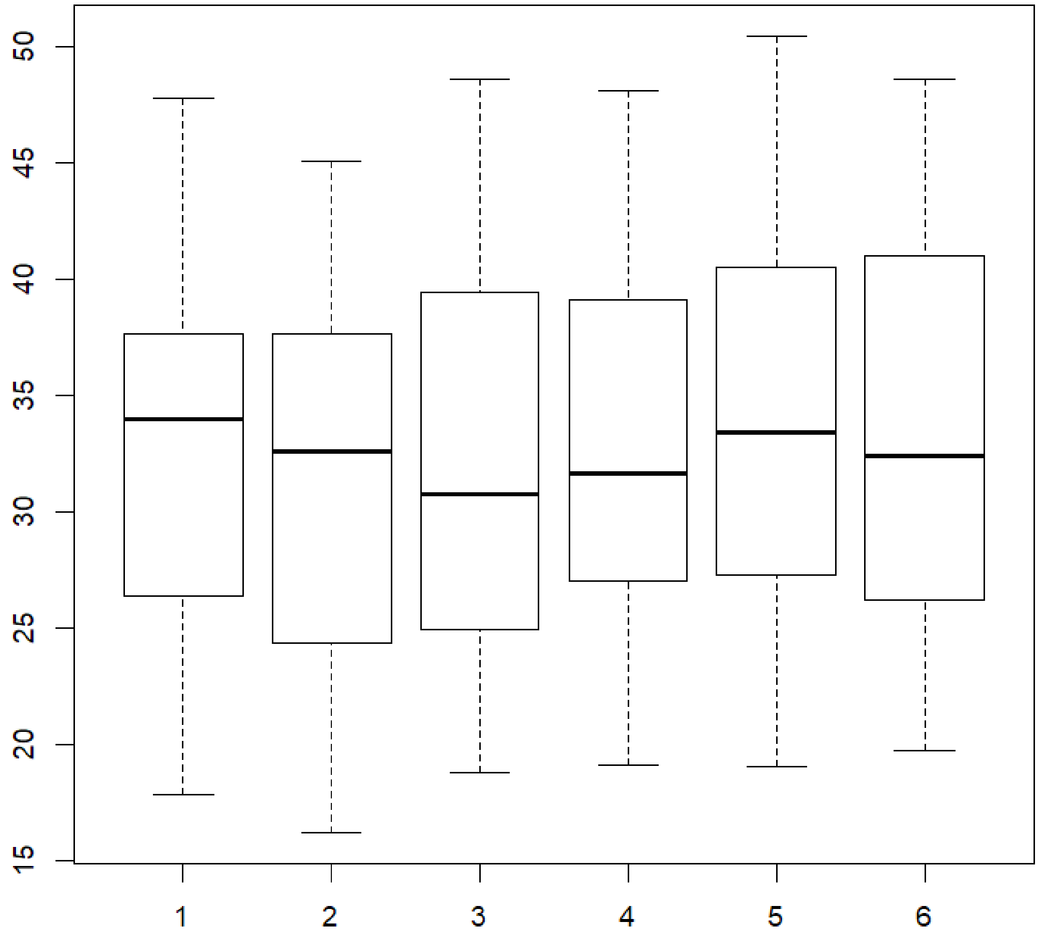

Figure 7.24: The both scaling and avatar hip-back rotation plotted in a boxplot.

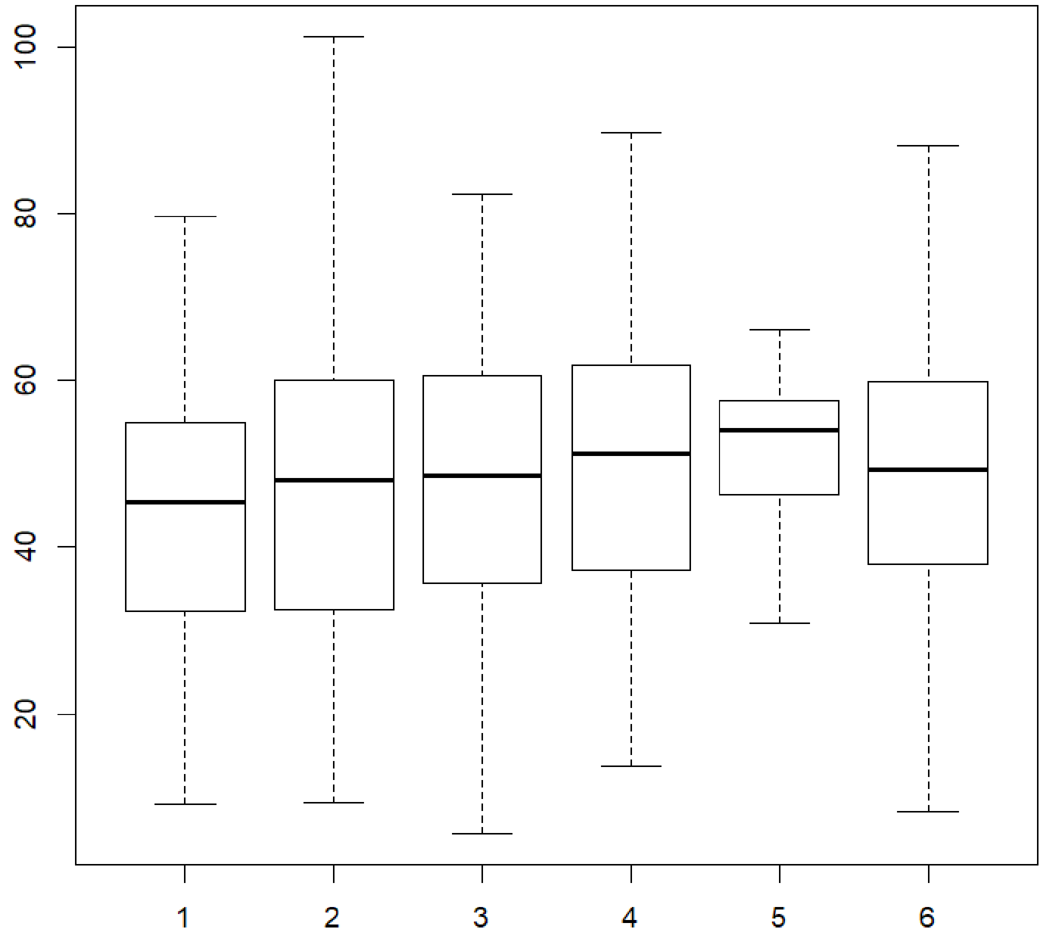

Figure 7.25: The both scaling and avatar hip rotation plotted in a boxplot.

Figure 7.24 and Figure 7.25 show the hip-back and hip-rotations between treatments plotted in boxplots. These were used to identify and remove outliers in the datasets. It can also be seen how alot of the data overlap indicating no significant difference between the treatments.

Still it was necessary to perform a Variance of Variance test to statistically show these results. These tests make assumption about the so it was necessary to know if the data was collected through repeated measures, and was parametric or non-parametric. To know if the data was normally distributed the Shapiro-Wilks test was used. The results of the analysis of the hip-back rotation can be seen on Figure 7.26a and the hip rotation can be seen on Figure 7.26b.

The results of the ANOVA on the hip-back can be seen Figure 7.27, while the results of the ANOVA test on the hip rotation can be seen on Figure 7.28.

```
Shapiro-Wilk normality test

data:  as.matrix(bothHipBackData)
W = 0.96979, p-value = 0.003721
```

(a) The results of the Shapiro-Wilks test for the both scaling and avatar hip-back rotation.

```
Shapiro-Wilk normality test

data:  as.matrix(bothHipData)
W = 0.97274, p-value = 0.009293
```

(b) The results of the Shapiro-Wilks test for the both scaling and avatar hip rotation.

Figure 7.26

```
Friedman rank sum test

data:  as.matrix(bothHipBackData)
Friedman chi-squared = 12.326, df = 5, p-value = 0.03059
```

(a)

```
Multiple comparisons between groups after Friedman test
p.value: 0.05
Comparisons
    obs.dif critical.dif difference
1-2    10.5     38.04453      FALSE
1-3     2.5     38.04453      FALSE
1-4     3.5     38.04453      FALSE
1-5    20.0     38.04453      FALSE
1-6    23.5     38.04453      FALSE
2-3    13.0     38.04453      FALSE
2-4    14.0     38.04453      FALSE
2-5    30.5     38.04453      FALSE
2-6    34.0     38.04453      FALSE
3-4     1.0     38.04453      FALSE
3-5    17.5     38.04453      FALSE
3-6    21.0     38.04453      FALSE
4-5    16.5     38.04453      FALSE
4-6    20.0     38.04453      FALSE
5-6     3.5     38.04453      FALSE
```

(b) .

Figure 7.27: The results of the ANOVA test for the both scaling and avatar hip-back rotation.

```
Friedman rank sum test

data:  as.matrix(bothHipData)
Friedman chi-squared = 13.531, df = 5, p-value = 0.01888
```

(a)

```
Multiple comparisons between groups after Friedman test
p.value: 0.05
Comparisons
    obs.dif critical.dif difference
1-2    18.5     38.04453      FALSE
1-3    25.5     38.04453      FALSE
1-4    34.5     38.04453      FALSE
1-5    35.0     38.04453      FALSE
1-6    45.5     38.04453       TRUE
2-3     7.0     38.04453      FALSE
2-4    16.0     38.04453      FALSE
2-5    16.5     38.04453      FALSE
2-6    27.0     38.04453      FALSE
3-4     9.0     38.04453      FALSE
3-5     9.5     38.04453      FALSE
3-6    20.0     38.04453      FALSE
4-5     0.5     38.04453      FALSE
4-6    11.0     38.04453      FALSE
5-6    10.5     38.04453      FALSE
```

(b) .

Figure 7.28: The results of the ANOVA test for the both scaling and avatar hip rotation.

7.3.5 Virtual Reality Sickness Questionnaire

In this section we show the results of the pretest and post-test VRSQ scores, with their means and standard deviations calculated. Answers in each category represented a score of 0 to 3. The score of the oculomotor parts are multiplied by $\frac{100}{12}$, and the disorientation parts are multiplied by $\frac{100}{15}$. The total score is then calculated as $\frac{Oculomotor+Disorientation}{2}$, giving the final score a range of 0-100. The complete results with the inbetween questionnaires can be seen in appendix C.

	PRETEST									
	OCULOMOTOR				DISORIENTATION					TOTAL
ID	General d	Fatigue	Eye strain	Difficulty f	Headache	Fullness o	Blurred vi	Dizziness	Vertigo	
1	0	0	0	0	0	0	0	0	0	0
2	0	0	1	0	0	0	0	0	0	4.166666667
3	0	1	0	1	0	0	0	0	0	8.333333333
4	2	0	0	0	1	0	0	0	0	11.66666667
5	0	1	0	0	0	0	0	0	0	4.166666667
6	0	2	1	2	0	0	0	0	0	20.83333333
7	0	1	0	0	0	0	0	0	0	4.166666667
8	0	1	1	1	0	1	1	1	0	22.5
9	0	2	1	1	0	2	0	0	0	23.33333333
10	0	0	0	1	0	0	0	0	0	4.166666667
11	0	0	0	0	0	0	0	0	0	0
12	1	1	0	1	0	0	0	0	0	12.5
13	1	2	1	1	1	1	1	0	0	30.83333333
14	1	1	0	0	1	2	0	0	0	18.33333333
15	1	2	0	1	0	1	0	0	0	20
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	1	0	0	0	3.333333333
18	0	0	0	0	0	0	0	0	0	0
19		1	0	1	1	0	1	0	0	15
20	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0
23	0	1	0	0	0	0	0	0	0	4.166666667
24	0	1	1	0	0	0	0	0	0	8.333333333
									M	**8.993055556**
									SD	9.289295586

Figure 7.29: VRSQ Scores before testing.

	POSTTEST									
	OCULOMOTOR				DISORIENTATION					TOTAL
ID	General d	Fatigue	Eye strain	Difficulty f	Headache	Fullness o	Blurred vi	Dizziness	Vertigo	
1	0	0	0	0	0	0	0	0	0	0
2	0	0	1	0	0	0	1	0	0	7.5
3	0	1	0	1	0	0	0	1	0	11.66666667
4	0	0	0	0	1	0	0	0	0	3.333333333
5	0	0	0	0	0	0	0	0	0	0
6	1	2	1	1	0	0	1	1	0	27.5
7	2	1	0	0	0	0	0	0	0	12.5
8	1	1	2	1	1	1	0	0	0	27.5
9	1	0	0	1	0	0	0	0	0	8.333333333
10	0	0	1	0	0	0	0	0	0	4.166666667
11	0	1	0	0	0	0	0	0	0	4.166666667
12	1	1	0	0	0	0	0	0	0	8.333333333
13	1	2	1	1	2	0	1	0	0	30.83333333
14	1	1	0	0	1	2	0	0	0	18.33333333
15	1	1	1	1	0	2	0	0	1	26.66666667
16	2	1	0	0	0	0	0	0	0	12.5
17	1	0	1	0	0	1	0	1	0	15
18	0	0	1	0	0	0	1	1	0	10.83333333
19	0	1	1	0	1	0	1	1	0	18.33333333
20	0	0	0	0	0	0	0	0	0	0
21	0	1	0	0	0	0	0	0	0	4.166666667
22	0	0	0	0	0	0	0	0	0	0
23	1	1	1	0	0	0	0	0	0	12.5
24	2	1	1	0	0	0	0	1	0	20
									M	**11.84027778**
									SD	9.526783902

Figure 7.30: VRSQ Scores after testing.

7.3.6 Ranking of test scenarios

In this section are the histograms created from the user rankings of the different scenarios based on three aspects. Each colour in the chart represents a scenario, the x axis is the rank and the y axis shows how many people voted on them for a given ranking. The complete results can be seen in appendix C.

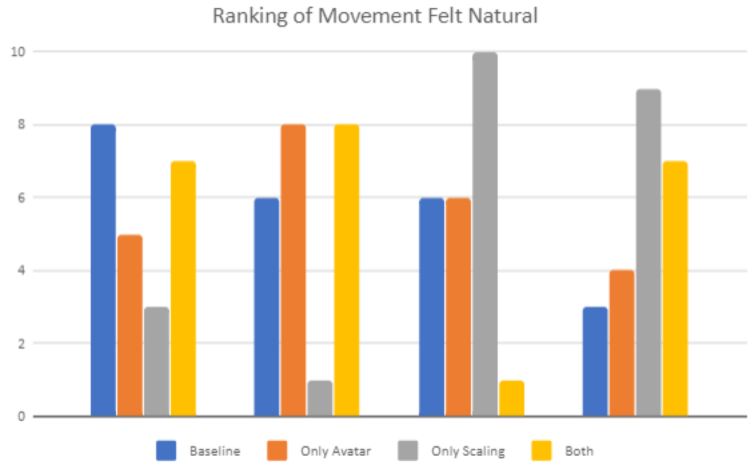

Figure 7.31: Histogram of rankings based on which scenario felt most natural.

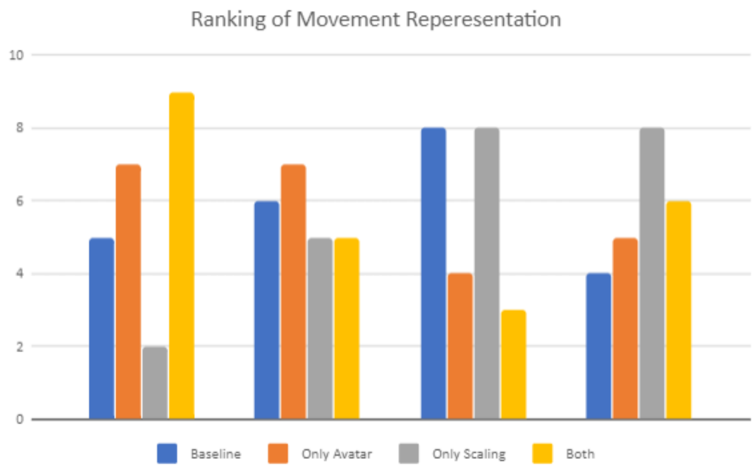

Figure 7.32: Histogram of rankings based on which scenario best represented their movements.

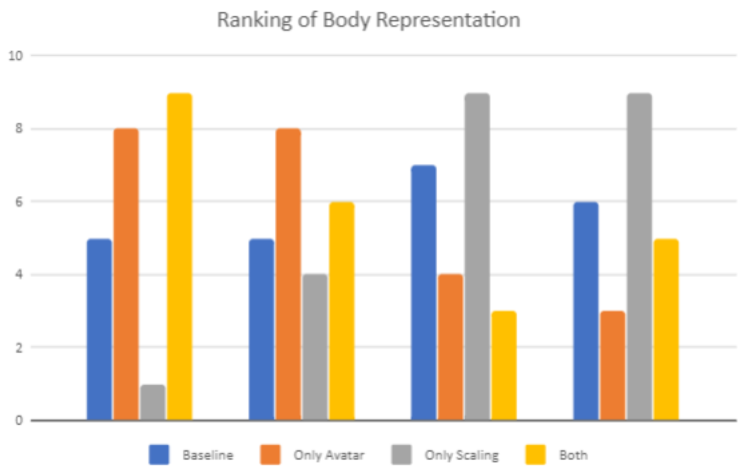

Figure 7.33: Histogram of rankings based on which scenario best represented their body.

7.3.7 Arc and Scoring Questions

Here are the results of the gamification part of the questionnaire. The users rated the usefulness of the arc that showed their hip and back rotations, the score under the arc representing their previous attempt and the monitor in the room showing their total score.

Arc	Score	Monitor
8	10	9
7	7	2
9	7	7
7	9	3
10	1	1
10	8	1
3	7	6
3	3	8
6	3	5
7	9	4
8	8	10
9	9	1
10	10	7
3	7	4
10	5	2
4	9	10
9	10	2
7	4	7
7	7	5
7	8	5
9	9	7
8	8	6
9	8	3
10	6	8
7.5	7.166666667	5.125
2.284160963	2.407717062	2.848531277

Figure 7.34: Ratings, mean and standard deviation for the arc, the current score below the arc and the total score on the monitor.

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A. Appendix

The following transcript is based on one provided by MTA18735 who were also present at the interview.

Martin: ″First we would just like to ask you to tell a bit about yourself and what you do.″

Mette: “Yes, I have a degree in physical therapy, but now I'm doing a master's degree in clinical science and technology, so a lot about implementing technology in health care so that's what my view is on. I have worked briefly before I started my master's degree but I don't have many years of clinical experience.″

Bo: “But you do have experience working with patients?″

Mette: “Yes.″

Martin: “Then we would like to first know if there are any important aspects you have to consider before you start a course of rehabilitation for a patient?″

Mette: “Well of course you have to know what is wrong with the patient, and then when you start the rehab, first you... if they have been in the hospital, there will be a [rehabilitation plan] issued, and then of course there will be maybe some diagnostics, like “there was a fracture on this and this vertebrae”, but if it's still.. if it's a patient who has just seen their normal doctor, the doctor can say “okay I will give you a prescription for physical therapy”, and then you sort of just have point blank, you don't know the patient at all, so depending on how and where you work, you might know a little bit about the patient beforehand. But otherwise you see the patient, we do like an interview, in our terms it's called an anamnesis where we talk about who they are, what are their symptoms, how is it affecting their lives, and if they have a job, does it affect their job, does it affect their family life, and we try to figure out what the problem is, but also what they want to return to and set up goals. What most physios (physio therapists), based on the international classification of EC, so we look at... there's on the body level, there's maybe this fracture, there are some muscles where there's an injury, okay how does that affect the function, can they walk, can they stand, can they bend down, can they not sit for a long time and then we look at activities, so if they have a leg fracture, how does that affect that... they are normally professional handball players how does that affect their activities anymore. So that's like the base of the rehabilitation and then once we figure out “okay they have problems doing these things”, we normally ask them to do... if it’s a low back pain, and they say “yeah, it’s a problem when I’m tying my shoes, then we may ask them to tie their shoes, so that we see how they move and if we can recall the pain and they say “yeah it hurts right here”, so we get a good view of what is wrong and of course we try to analyze what might cause the pain and then we might do some more specific tests there are like validated tests for each body part. There’s a TUG test, which is like you stand up and then you walk, I think, three meters, turn around this cone and then walk back and sit back down. It’s like a typical standard test. So depending on how long you spend doing it you get a certain... you write the time down, or you can see “okay it’s a problem for them to turn”, so we also analyze where is the problem? Is it standing up? Is it sitting down? Is it walking? Is it turning? Depending on each patient we might decide to do different things. And then once we figure out what the problem is, we can give them exercises normally, and we can maybe do some exercises at the facility, or they can have some exercises to do at home. There can also be manual therapy, there can be where we perform mobilization. Let’s say there’s limited mobility and you can use a number of techniques to increase mobility. So there are different manipulations, you can do for like the spine typically. So it’s hands-on stuff or sometimes we can also massages, it’s not very often that physios do that. But I think mainly it’s exercise therapy that we use now, like there might be some manual therapy that we do to optimize the exercises, but if it’s in a private clinic... you can quote me on this, since I wrote that down, but I think there’s more work with the patient versus the therapist, they do some acupuncture or some manual therapy, and then they go back home whereas I think in the public rehabilitation it’s way more exercise based where there’s less manual therapy. But of course there’s always exceptions, and then I also think many do classes, for like knee rehabilitation or back rehabilitation, so it’s like multiple patients and one therapist. Which also depends on if we think that they are able to participate, then in the public system, you get a certain amount of hours per patient depending on the diagnosis, so some will have like 9 therapist hours, but if we put them in a class, even though they are there for an hour, they only have 15 minutes of therapy, so of course they can come to the class many times with the same 9 hours, but that all depends if it’s a very confused patient, or if it’s something really difficult that demands the therapist to be there the entire time, of course... but for the main part, if it’s possible, we put them in a class. But I think private and public work very differently. Because privately it’s all about the money, where publicly it’s all about goals, we are allowed to do this, so we do this.

Rasmus: “Well you mention that there both exercises at the clinic, but there is also some you get for home. Is there a difference between the exercises?”

Mette: “Normally you have more equipment at the facility, so if it’s like a leg press that you don't have at home then you come there and do that maybe twice a week. So it's very typical that people lack lower limb strength, so of course when they go there, they do a leg press, and then we say at home you can do 10 squats, three times day. Many times it's like the heavy stuff or the difficult stuff you do at the clinic, and at home you do basic stuff and some things you also need to do everyday. If it's a patient that has to do stretches, of course if they only come in once a week, you need them to do it everyday, and some people need to do it more times a day. So it's typically not the same things they do."

Bo: "You said in public clinic, there are more facilities for exercise. What type of facilities are you talking about?

Mette: "Normally it's like a gym, but also in the private clinics now, a lot of them have like a small gym, some machines, some TheraBand, the elastic rubber."

Bo: "It's all the (nourishing???) facilities? Or some special?"

Mette: "I would say if you go to FitnessWorld, there are a lot of machines, and weight lifting stuff. If you go to a gym in a physical therapist's clinic, there will also be the weightlifting stuff, but there will be way more TheraBands, and balance balls, all that stuff. I think we have more balance things, and maybe equipped better for the elderly I would say."

Rasmus: "You did briefly talk about how you assessed injury, there was the TUG test you mentioned but are there any other particular ways that you would look at a patient and figure out what is injured and how severe is it?"

Mette: "If it's a back patient, I would first ask them to bend in all the different directions, and then I will ask them to take their clothes off, so I can see the back and probably also their legs, because sometimes it's a problem in their lower limbs that is causing the back pain. So to see if there's like a difference in length, so if one leg is shorter than the other, that might cause the back pain so I assess the body, what it looks like, and when they do different movements if they are restricted, and then of course the patient says "bending forward, that hurts, bending backwards, doesn't hurt". We also often use a numeric scale of pain, where we ask "from a scale of 0 to 10, how much pain are you in right now, how much pain are you in when you do this", so we use that to rate. First we normally do isolated movements, so you first bend over, and then in that direction, so it's very isolated, only one thing happens at a time, and when you have seen that you progress to a function, like walking or lifting something up and then the standardized test, it can be used sometimes for diagnosis, but often times it's also.. if you know that they do worse than the average, it's a sign that something is wrong and then sometimes we use like… the first time you came in here, you could only do this.. it took you 40 seconds, but now it only takes you 10 seconds, so it's also an effect goal.

Rasmus: "So it seems like some of the standardized tests might not be super useful unless you can apply it to the individual? To see how they have progressed through these…"

Mette: "Yeah, often times it's to see if they get better but some of these tests do also have (???) based.. say, if you are in your 60's, you should be able to do this within this time limit, because of course it can depend on age and if you have a particular disease…"

Bo: "Is there a guideline for at what age you should be able to do what?"

Mette: "For some of the tests, more extensively than others, depends on how much research has been done on that particular test, so some tests will have for age, normal people in all ages have done this, and then you say okay the average in this decade is this and then they perform way worse, then that might be a problem, but also within a specific diagnosis, they have also done on Parkinson's patients, they can do this test, in this time frame."

Robert: "I was wondering when you talked about for example when doing the bending to assess like these specific motions, is it bend as far as it's still comfortable, or…?"

Mette: "Of course we don't want to provoke more pain than we have to, but we also have to know, what will cause pain. But we will ask them to bend as far as they can, but often times they stop when it hurts too much, so that just happens automatically. But some patients, and there you have to look at the patient, and you have to get to know the patient, are they someone who will, because you told them that they have to do this exercise, they will do it and be in a lot of pain, or is it someone who is very "I don't want any pain, I'm just gonna bend over 10 degrees and then it hurts a little bit and then I'm not gonna do any more"."

Bo: "Do you usually evaluate their fear-avoidance level?"

Mette: "I think we look at everything we do with the patient, and from the initial anamnesis… we don't have a specific test saying how much fear-avoidance does this patient have, it is based on all our clinical observations, and the talk with the patient, at least I'm not aware of a scale of fear-avoidance, but it is something that is very common in many patients with pain, but it's not something you necessarily detect on the first visit. It's when you start doing exercises, or you look at how the patient undresses, if they do it in an odd way, that might be a sign that they are avoiding certain movements, so it's something we definitely think about."

Bo: "You just mentioned, you test the ability to do some isolated movements, are there some cases, in which the patient can left bend, but not right bend at all?"

Mette: "Yes. That is possible. It can be because of many things, there can be some joints in the back that are locked so it is not physically possible or it can be because they are afraid to do the movement, they activate their muscles, their antagonists, so that they don't move because there's so much muscle tension."

Bo: "I think in this case if a patient has no problem at all with left bending, but he can't right bend, are you going to specifically train right bending?"

Mette: "Yes. But first I will try to find out why he can't bend, because it might be a mechanical problem or it might be a neurological. . . "

Bo: "If it's neurological, what do you do?"

Mette: "It often times have to do with motor control or if they have been in pain then there are of course some adaptions to the nervous system, that will maybe cause the antagonist muscles to fire. . . antagonist is like, there is for example in the arm if you bend your arm, then the biceps is the agonist and there are some muscles that move in that direction, but then on the other side of the arm there are some muscles that make the opposite movement, so it's agonist and antagonist. If I'm trying to move in one direction, but my antagonist muscles are active, I can't, because they are holding the arm back, or the back. So if the patient has been in pain, the muscle activation patterns are different, when yes maybe there was an injury initially, but then now the actual injury is gone but because it hurt for a while, then the muscles are active in a different way, so that the patient is not moving as he should, because he's still afraid that it's gonna hurt, and it might hurt, not because there is a pathology, but because the nervous system is more sensitive now, and sometimes if the patient can't move to the right we figure out is there a mechanical problem like in the bones or the muscle that is too tight, is there a problem there or is it simply just because they can't activate the right muscles at the right time, or is it a mix? So if it's them not activating the right muscles at right time, we have to relearn that movement, and then we focus our exercises on that. The patient has to learn that it is not dangerous to move in that direction."

Bo: "Would it be possible if we train the right bending, still in this example, that will cause some risk of further damaging?"

Mette: "In some cases, yes. If there is a mechanical problem, if there is a protrusion. . . of course if you bend, and you squeeze the disc, of course it can cause further damage, but with any treatment, you should not treat them before you know what structure is causing the problem. Sometimes you can't know... let's say we are using the VR technology, and I'm not entirely sure why my patient won't move, then I would think "okay I'm gonna be very careful with this patient", and I will watch him do it, and not just give it to him and say to him yeah, take it home and use it. As a therapist I have the responsibility that whatever he is doing is not dangerous for him, so if I was in doubt if it could damage the tissue further by bending to the right, I would try to figure that out before I did some very drastic... So yes, there is a risk."

Bo: "Do you think it would be a good.. you can continue"

Mette: "No it's just if you have a product, it should of course be a specific thing, there are these risks and if the patient is this and this and this, you should not use it. Or if he has this problem, you should be careful. But it's with everything. Anything you use with the patient, you have to be sure that it's safe for them and sometimes if the patient, if he knows there's a risk, but he can't find anything else that helps, he says okay I'm going to try it anyway, it's my own responsibility. But of course it's up to him."

Martin: "Based on that, are there any general movements for patients for lower back pain that they should avoid doing, that could further injure them? Just generally."

Mette: "No? I don't know if it's easier for you if I explain in Danish with the slipped disc? [So if you have a slipped disc it's like... It's like round, and it's between all the bones? Vertebrae. They sit between those, but a fissure might appear in it actually, on one side, so if you bend to the other side, then nothing happens, but if you apply pressure to some damaged tissue, or if it's an actual slipped disc, where there is something soft, that because the fissure, then it runs out, and that's what hurts a lot and it might run out and hit the nerve. So yeah, it might be dangerous to bend in a specific direction. But the thing with a slipped disc is that that's where the fissure happens, so it runs out, then it takes 8-12 weeks, then the body has generally regenerated so the danger should have passed. But if you have a beginner, so it could go wrong, then of course you would try to train in a way that ensures that it won't go wrong, but it is still important to get as much exercise as possible, then it might not be a smart idea to stand while holding 40kg at the same time, but it is important for this disc to remain healthy, then you have to move in every direction. Then that's the way in which it gets its nutrition, so movement is actually pretty important. So as a default we want the patients to move as much as possible without it hurting excessively. When you get acute back pain then earlier it was a lot like "by all means don't move, you have to lie in the bed, uha, you can't do anything", where now it's recommended that you move as much as possible without it worsening your pain a lot. But of course, if you have a slipped disc, which just happened, or if you have a fissure which might go really wrong, then you shouldn't overexert, so it's about finding the right level. But I can't imagine that what you plan to do in VR is without weight, that then it generally wouldn't be... Then it wouldn't be worse that what you would normally walk around and do in your everyday activities. If you think you're going to apply weight, it could be relevant later in the course to actually put heavy weights on.]

Bo: "But these type of patients if they are not non-specific, they have a specific pathological cause, then that can be identified right?"

Mette: "Yes."
Bo: "Okay. So I guess most, I have read from literature that 90% of the chronic back patients are non-specific, so for those patients, there should be no risk of doing anything if I understand correctly."

Mette: "No. If they have done all the testing they can do and they can't find an obvious answer for a specific pathology, yes then it is important that they move. But many times if there has been a pathology earlier, they do something called "bracing", because they have learned that you need to protect your back, so they activate all their muscles, like in their stomach and in their back, someone that bend over they are very stiff, which can sometimes increase the pain because when the muscles are so active, it can activate other sensory parts, the nervous system, so they still have the pain, because they are actually just tensing too much. That's a common problem, so our job as a therapist is that they activate the right muscles, not just the whole pack at once."

Bo: "What do you mean with right muscles?"

Mette: "That depends on the movement they do of course."

Bo: "It's not the muscle on the back?"

Mette: "No, if you do one movement of course you know there are different muscles on the back that you can activate, but sometimes the problem is that they activate too much. Too much in too many muscles. So it's just because they activate so much that that causes the pain or at least makes it worse. But there's often times a huge psychological part in chronic pain."

Martin: "Is there a big difference between sitting and standing when you are doing exercises for lower back pain especially?"

Mette: "When you sit, there can be a higher load on the back than when you stand."

Bo: "Maybe we can ask in another way, do you usually rehabilitate the patients while they sit while training? Or do they always stand up?"

Mette: "They can do both, mostly I think we would have them standing but if it's about relearning doing particular tasks, like if it's a secretary who sits a lot, then she knows that when she reaches out to take a pen, then that hurts, the way that she contracts her muscles is wrong, which does this, then she has to learn to do it in a better way. When you do a movement there are multiple ways to get the same result. Like if I'm grasping my cup, I can have a straight back and bend forward, or I can do this (demonstrating), so I can get the result, but my back was doing something different. Sometimes with back patients, if there has been a pathology, so there is an injury, like you can never totally get rid of this, they have to compensate or find other ways to do things because we want them to be as active and have as much function as possible so if we know this patient has. . . after surgery he has had three of his vertebrae fused, so one particular part of his back can't move any more and it's never going to, then of course he has to figure out how to move his back in a different way. So maybe I'm not really giving specific answers, but that's also because patients can be very different and there can be so many things wrong and the way you treat them can be very different."

Rasmus: "In the beginning you mentioned that when you sit down with the patients you together figure out what the goal of the rehabilitation is. Is there any specific way you will know when this rehabilitation course has been a success? Or is it just back and forth between you and the patient?"

Mette: "Then sometimes we use the tests or we can have one function saying the patient wants to be able to tie his shoes. So when he comes in, he can't do it, we train him for 12 weeks, then we re-test, can you tie your shoes now, he can, and that was a success. But often times it's also they want to be able to go for a run again, or they want to be able to go to work and not have pain, so we try to make their goals as specific and measurable as possible. We have to be able to say, did we succeed, yes or no."

Bo: "So you evaluate the success based on specific tasks? Do you individualize the tasks?"

Mette: "Yes, sometimes we have one of the standardized tests that we use, if it fits. Sometimes back patients they can't walk very far, because if they walk a little bit and then they are in pain, they have to stop. So if one patient has problems walking because of his back pain, then maybe doing a 6 minute walk test would be a way for him to evaluate, or for us to evaluate the success of the rehabilitation. But if another patient, if his problem is that he can't swim, then that is the task that we evaluate on, is he now able to swim? Or it's going to work without having to take pain killers, that can also be the goal of the rehabilitation, so it's really what is important for that specific patient."

Rasmus: "Is this measured like the same, there was the mechanical and the neurological... neurological was the one with the fear-avoidance, right? Would that fall into that category?"

Mette: "Of course there can be a neurological pathology, but many times it's more about the motor-control, or if this area has been made more sensitive for some reason, then that affects how they move, because there can be different reflex patterns, for example, we need to change for them to diminish the pain."

Rasmus: "Okay, so if a patient walks in, and you see, okay this is mostly because of fear-avoidance that he can't do these movements, do you still do this specific task to figure out if the rehabilitation course has been a success?"

Mette: "Yeah, so of course it doesn't depend on what caused the problem, it depends on what the problem is, and what the patient wants fixed or what he wants to be able to do. Sometimes you can't really change the pathology but you can change their function."

Bo: "What I understood is fear-avoidance is a psychological dimension, so it could happen in patients with neurological problems or mechanical problems."

Mette: "Yeah, like fear-avoidance is basically just being afraid of mainly pain, and then you avoid doing what causes the pain."

Rasmus: "Yes, that's how I understood it as well."

Bo: "More questions?"

Martin: "I think we just have about what... cause you have had experience with technology rehabilitation and we would just like to hear about what sort of technologies and what experience you have."

Bo: "Do you mean some devices or treatments, therapy?"

Martin: "For example, yeah, because we are working with VR, so we would first ask if you have had any experience with VR as rehabilitation and then if not, what else?"

Mette: “Unfortunately, no.”

Bo: “I don’t think it’s available in the market yet.”

Mette: “I know some of my classmates are actually trying out… there’s like a trial thing in Aalborg municipality, with VR for different things. I’m not sure what… one is for psychiatric patients, can’t remember what the other one is, but my understanding of technology is not necessarily that you can plug it in to something, so a technology can also just be a specific training regime, so the way I define technology is very much based on what I study, so of course we use technologies, namely a material or immaterial thing, but… if you are more asking about a certain device, I don’t think I have really tried any. It’s very low-tech we have been using.”

Bo: “If it’s exercise-based, and you said most of the prescribed therapy would be exercise-based, ad you said that exercise-based therapy would involve some machine, and I have read from my (???) that there are some other technologies you can use for pain therapy, like ultrasound, near infrared, radiating some warmth…”

Mette: “I don’t have much experience, I think I have used infrared on a couple of patients… or was it laser? Laser is quite popular exactly, I don’t how much it really... I think there is a big placebo. I haven’t really read up on the latest research but I think many of these are… for ultrasound there might be an effect in a very acute stage, but otherwise it has no effect at all, I would say what I have most faith in is acupuncture actually. With (TENSE?), some people also define it only as activating the central nervous system whereas others use the term in also activating motor nerves… so there might be different… I don’t know what the guideline says…”

Bo: “It is not recommended in the guideline. I think the most recommended is the exercise.”

Rasmus: “When you asked you if you had tried VR, you said unfortunately no, so it’s just what kind of potential can you see in VR in rehabilitation?”

Mette: “What I would very much like to see, how you would build it for low back pain, because I have a very specific narrow interest in VR, being in phantom limb pain, so that’s sort of my knowledge about VR. I don’t have the imagination for how it would work with low back pain.”

Bo: “You are very much welcome to try the systems.”

Mette: "But I think like developing it, it has to make sense for the user, but I'm sure you also learn user-involvement stuff... if they can't see the relevance of technology, they won't use it. That's with everything. You have to make it relevant to the user, you have to tell them why it's important they do the very boring exercises that might cause pain right now but actually in the long run it could make you better."

Bo: "That's why they are going to develop some games in the exercise. So this is one of the benefits for using VR."

Mette: "It sounds really interesting. But I think even if you have a really good product, it has to be affordable."

Bo: "Affordable to the therapist or the patient? I think it makes more sense to buy the system by a physical therapist, right?"

Mette: "Yes, but the thing is that if it's a very expensive system of course the therapist has to think "I have a potential here", but the user has to pay for it if it's a private clinic and then if it's in the public rehabilitation the patients don't have to pay, so whatever technology they use there, is free for them. It's only the county or the region that pays, but if it's in a private clinic, the patient pays. And I know for some of the technologies you mentioned, it's quite pricey so maybe the session with the therapist is 150-160 crowns, but if he uses this technology, it's like another 200 crowns, and that is not subsidizes, so... it's getting into detail but I think that can cause a technology to fail because using the separate technologies be it laser or acupuncture or VR 100% of that bill is on the patient, so if they don't see that it's effective, they may not to pay for it. But in the public system, but they normally don't have the fancy technology, so..."

Bo: "Fortunately the VR system would not be so expensive right?" (Talk about VR, how it gets cheaper every year)

Mette: "But can you use off-the-shelf?"

Rasmus: "There are some headsets that you don't need to throw up some light towers to know where you are, but then you need extra sensors to know where you are. But the Vive headset that we are using you can just buy off the shelf and set up at home. Plug it into your PC and use it."

Helene: "Well we also wanted to know exactly what kind of exercises they do, what kind of movement do you always suggest they do for lower back pain and how they should do for example exercises at the clinical, like do they do some twists or is that mostly at home, or that kind of stuff."

Mette: "It depends, because they can do all sorts of movements, because some exercises are for strength, so you can do like arch holds, so just lie on your back and then extending. Or you can do, if it's sometimes for rotation, you can have a handle and then there is a weight attached, or a TheraBand, and you use the core or if it's... sometimes, if there is a pathology, like if the disc is about to slip, you can do a a really good regime where you do back extensions, lie on your stomach and then extending very far, but if the slip is in a different direction you have to do like a (lateral) band? Pretty much any exercise that strengthens the back or the stomach, the stomach is also very important, because lot of the times back pain is because your stomach muscles are weak."

Helene: "So do you suggest that they move in all directions as much as they are physically able to do?"

Mette: "Yeah, that's like the general advice we give them, move as much as you can without causing excessive pain, but then of course the exercises, the specific exercises you do can... Sometimes it's also if it's a lot about the motor-control, you can do a you are lying on your back, and then you are actually just moving your legs, because your back also moves when you move your legs. There can be like a thousand different exercises..."

Bo: "But these kinds of exercises can easily be done at home?"

Mette: "Yeah, most of them. It's more when you need like heavy weights or if the patient is very bad at knowing what they are doing, then you need someone to look at the quality of the exercise so I would think, before they can do anything at home, you have to make sure that they understand the exercise and they can do it with good quality, because with everything, the quality makes the difference. If I told my patient to go home and move the leg, well lying on your back, and they did that without stabilizing, so you know, they did it 3 times a day, moving my leg and they didn't get any better, that's because they were doing it wrong. Really, the quality is very important in many cases."

Bo: "If our VR system can monitor the exercise, would that sound good?"

Mette: "Definitely, because I don't know how you are using motion sensors or kinematic, like different angles of different joints, but if that can be integrated, I think that would make all the difference. But let's say if we are... if they do it right, and then they score a goal in their game, they are not necessarily able to reproduce the same movement in other functions, but there is a huge carry over effect. We are trying to make whatever they do as functional as possible. First we do simple exercises, very isolated, one joint is moving, and then as it gets better, you involve the whole body. So it's good that you know how to stabilize your core, but if you can't stabilize your core while you are dancing or lifting a box... so we also have to train that."

Bo: "I have a last question, when you do training with the patient, do you usually have a time limit for each training session? Usually how long do you treat them for one session?"

Mette: "Yes. I think private it's mostly 25 minutes."

Bo: "25 minutes without a break or there are some breaks in between?"

Mette: "Most clinics do 25 minutes. And then of course you can pay for a double session, but in the public it's normally one hour."

Bo: "I guess within the 25 minutes there should be some breaks between?"

Mette: "Oh yeah if you are doing exercises, you have a small break, but from the patient enters the door until they leave it's 25 minutes."

Bo: "If we use VR game, ask the patents to play a game, do you think after how long time we should ask them to have a break?"

Mette: "Some, maybe 10 minutes, it depends on how difficult it is, you know, the muscles might be exhausted, or if they are in bad shape... yeah it depends on how active they are. If you are doing just normal exercises, you can say, you can say 3 x 12 reps, is normal and then you have a short break, and then you do another exercise, so I would say each exercise is normally 3-4 minutes. But if it's resistant training, you can't continue very long, maybe like a one minute break.

Bo: "It depends on the exercise itself and the patient then?"

Mette: "Yes. It also depends on what kind of strength you want to build. So there are so many things you can adjust, depending on if you want to be very strong, or you want to be very fast, if you want to build force very fast, you train very differently than if you want to lift very heavy weights. But if it's more for you want to be able to continue for a long time, you have to use a lower weight, often times it's your own body weight, how you are positioned determines how hard it is for the muscles to work. So if you have to work against gravity or..."

B. Appendix B

Participant no.:	Positive scaling																			
Gain:	0.02		0.04		0.06		0.08		0.1		0.12		0.14		0.16		0.18		0.2	
Scaled	*		*		*		*		*		*		*		*		*		*	
User reported	/	/	/	/	/	/	*		/	/	1		2		3		4		5	
Discomfort															16					
Participant no.:	Negative scaling																			
Gain:	-0.02		-0.04		-0.06		-0.08		-0.1		-0.12		-0.14		-0.16		-0.18		-0.2	
Scaled	*		*		*		*		*		*		*		*		*		*	
User reported		6	7			8		9	10		11		12		13		14		15	
Discomfort																				

Figure B.1: Data from Participant 1.

1. Right side was bigger angle the second time
2. Same as 1.
3. Same as 1.
4. Left side was further back second time
5. Boxes further back the second time
6. Boxes further back than before
7. Boxes moved more to the back
8. Same as 7.
9. Neck stretched less
10. Angle was greater
11. Angle was greater (had to move head more)
12. Neck stretched more
13. Had to stretch neck more
14. Had to stretch neck more the first time
15. Had to stretch neck more the first time

Participant no.:	Positive scaling																			
Gain:	0.02		0.04		0.06		0.08		0.1		0.12		0.14		0.16		0.18		0.2	
Scaled		•		•		•		•		•		•		•		•		•		•
User reported	/	/	/	/	/	/	/	/	1		/	/	2		3		4		5	
Discomfort													14							
Participant no.:	Negative scaling																			
Gain:	-0.02		-0.04		-0.06		-0.08		-0.1		-0.12		-0.14		-0.16		-0.18		-0.2	
Scaled		•		•		•		•		•		•		•		•		•		•
User reported	/	/	/	/	6			7		8		9		10		11		12		13
Discomfort									15				16						17	

Figure B.2: Data from Participant 2.

1. It was harder to do first movement, had to bend neck more
2. First one was a bit harder
3. Same as before, but unsure
4. First one was more difficult
5. Same as before
6. First one was easier
7. Second one was more difficult
8. Same as 7.
9. Same as 7.
10. Same as 7.
11. Same neck strain they thought
12. Second as much more difficult
13. Same as 12.
14. Maybe if bent neck more
15. Feel like stretches more
16. Cracking in neck
17. Getting more and more difficult

Participant no.:	Positive scaling																			
Gain:	0.02		0.04		0.06		0.08		0.1		0.12		0.14		0.16		0.18		0.2	
Scaled		*		*		*		*		*		*		*		*		*		*
User reported	/	/	1		/	/	/	/	2			3	4		/	/	5	6		7
Discomfort																				
Participant no.:	Negative scaling																			
Gain:	-0.02		-0.04		-0.06		-0.08		-0.1		-0.12		-0.14		-0.16		-0.18		-0.2	
Scaled		*		*		*		*		*		*		*		*		*		*
User reported	/	/		8	/	/		9	/	/		10		11		12		13		
Discomfort																				

Figure B.3: Data from Participant 3.

1. Had to move head more the first time
2. Same as 1.
3. Moved less the second house
4. Had to move head more to the left
5. Moved more to the left first time
6. Moved more to the right second time
7. Moved less the second time
8. More movement required in the second one
9. Second time more movement required to the left
10. Second time more turning was required
11. Moved head lot more second time
12. More movement the second time
13. Same as 12.

Participant no.:	Positive scaling																			
Gain:	0.02		0.04		0.06		0.08		0.1		0.12		0.14		0.16		0.18		0.2	
Scaled		*		*		*		*		*		*		*		*		*		*
User reported	/	/	/	/	/	/	/	/	/	/		1		2		3		4	/	/
Discomfort									13											
Participant no.:	Negative scaling																			
Gain:	-0.02		-0.04		-0.06		-0.08		-0.1		-0.12		-0.14		-0.16		-0.18		-0.2	
Scaled		*		*		*		*		*		*		*		*		*		*
User reported		5	/	/	/	/		7	/	/		8		9		10		11		12
Discomfort			14																	

Figure B.4: Data from Participant 4.

1. Maybe second is closer
2. Second seemed closer
3. In the second one the targets were closer
4. Second movement felt faster
5. This one is further
6. Second try was further
7. Same as 6.
8. Same as 6.
9. Same as 6.
10. Same as 6.
11. Second is really far away
12. Head turning caused discomfort
13. Neck hurts b/c headset is heavy

Participant no.:	Positive scaling																			
Gain:	0.02		0.04		0.06		0.08		0.1		0.12		0.14		0.16		0.18		0.2	
Scaled		*		*		*		*		*		*		*		*		*		*
User reported	/	/	1		/	/		2	/	/		3		4		5	/	/	/	/
Discomfort									6								7		8	
Participant no.:	Negative scaling																			
Gain:	-0.02		-0.04		-0.06		-0.08		-0.1		-0.12		-0.14		-0.16		-0.18		-0.2	
Scaled		*		*		*		*		*		*		*		*	*		*	
User reported	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Discomfort			9																	

Figure B.5: Data from Participant 5.

1. Red boxes are further apart in both cases
2. Red blocks got closer
3. Things moved a bit to the left
4. Rotation was more for second movement
5. Seems like to the right they rotate further
6. Noticed that movement was sometimes easier
7. Could reach it but does not know why
8. Feels like room is moving
9. Not much different but can't reach box

Participant no.:	Positive scaling																			
Gain:	0.02		0.04		0.06		0.08		0.1		0.12		0.14		0.16		0.18		0.2	
Scaled		*		*		*		*		*		*	*			*		*		*
User reported	/	/		1	/	/		2		3		4	5		/	/		6		7
Discomfort																				
Participant no.:	Negative scaling																			
Gain:	-0.02		-0.04		-0.06		-0.08		-0.1		-0.12		-0.14		-0.16		-0.18		-0.2	
Scaled		*		*		*		*		*	*			*		*	*			*
User reported		8		9		10		11		12		13		14		15		16		17
Discomfort																				

Figure B.6: Data from Participant 6.

1. Didn't have to turn neck as much
2. Same as 1.
3. Same as 1.
4. Same as 1.
5. Same as 1.
6. Same as 1.
7. Had to move more
8. Same as 8.
9. Same as 8.
10. Same as 8.
11. Had to move more but the boxes were closer together
12. Had to move more
13. Move less for second one
14. Had to move more
15. Same as 15.
16. Had to move less
17. Had to move more

Participant no.:	Positive scaling																			
Gain:	0.02		0.04		0.06		0.08		0.1		0.12		0.14		0.16		0.18		0.2	
Scaled		*		*		*		*		*		*		*		*		*		*
User reported	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Discomfort																				
Participant no.:	Negative scaling																			
Gain:	-0.02		-0.04		-0.06		-0.08		-0.1		-0.12		-0.14		-0.16		-0.18		-0.2	
Scaled		*		*		*		*		*		*		*	*			*		*
User reported	/	/	/	/	/	/		1		2		3		4		5		6		7
Discomfort																				

Figure B.7: Data from Participant 7.

1. Had to move further
2. Same as 1.
3. It was longer to the right
4. Had to move further
5. Had to move less
6. Had to move further
7. Had to move less

Participant no.:	Positive scaling																			
Gain:	0.02		0.04		0.06		0.08		0.1		0.12		0.14		0.16		0.18		0.2	
Scaled		*		*		*		*		*		*		*		*		*		*
User reported	/	/	/	/	/	1	2	/	/	/		3		4		5	/	/	/	/
Discomfort																				
Participant no.:	Negative scaling																			
Gain:	-0.02		-0.04		-0.06		-0.08		-0.1		-0.12		-0.14		-0.16		-0.18		-0.2	
Scaled		*		*		*		*		*		*		*		*		*		*
User reported		6	/	/	/	/	/	7	/	/	/	/	/	/		8	/	/	/	/
Discomfort																				

Figure B.8: Data from Participant 8.

1. Felt more precise
2. The left side feels more precise
3. Second movement one felt faster
4. Same as 3.
5. Same as 3.
6. Second movement felt more sensitive
7. Second felt harder to align due to jittering
8. The second one was jittery

Participant no.:	Positive scaling																			
Gain:	0.02		0.04		0.06		0.08		0.1		0.12		0.14		0.16		0.18		0.2	
Scaled		*		*		*		*		*		*		*	*			*		*
User reported	/	/	1		2		/	/	3		4		5			6		7	8	
Discomfort																				
Participant no.:	Negative scaling																			
Gain:	-0.02		-0.04		-0.06		-0.08		-0.1		-0.12		-0.14		-0.16		-0.18		-0.2	
Scaled		x		x		x		x	x		x			x		x	x			x
User reported	/	/		9		10		11	12		13			14		15	16			17
Discomfort																				

Figure B.9: Data from Participant 9.

1. First one required more movement
2. Same as 1.
3. Same as 1.
4. First one required way more movement
5. Same as 4.
6. Second one needed a little more movement
7. Second one was easier
8. First one needed more
9. Second needed a bit more movement
10. Second needed way more movement
11. Same as 10.
12. First one needed more movement
13. Same as 12.
14. Second one needed way more movement
15. Same as 14.
16. First one way harder
17. Second one way harder

Participant no.:	Positive scaling																			
Gain:	0.02		0.04		0.06		0.08		0.1		0.12		0.14		0.16		0.18		0.2	
Scaled		*		*		*		*		*		*		*		*		*		*
User reported	/	/	/	/	/	/		1	/	/	/	/	/	/	/	/	/	/	/	/
Discomfort																	3		4	
Participant no.:	Negative scaling																			
Gain:	-0.02		-0.04		-0.06		-0.08		-0.1		-0.12		-0.14		-0.16		-0.18		-0.2	
Scaled		*		*		*		*		*		*		*		*		*		*
User reported	/	/	/	/	/	/	/	/	/	/		2	/	/	/	/	/	/	/	/
Discomfort																				

Figure B.10: Data from Participant 10.

1. Distance in the second movement feels shorter
2. Distance feels slightly longer
3. Room feels spinny
4. Room is rotating more

POSITIVE	0.02	0.04	0.06	0.08	0.1	0.12	0.14	0.16	0.18	0.2	
Participant 1	-	-	-	*	-	*	*	*	*	-	Felt that unscaled was "further back" / Neck stretching reported at 0.16
Participant 2	-	-	-	-	*	-	*	*	*	*	They reported unscaled was more difficult
Participant 3	-	*	-	-	*	*	*	-	*	*	Reportedly scaled needs less head movement.
Participant 4	-	-	-	-	-	*	*	*	*	-	Reportedly in scaled, targets seem to be closer
Participant 5	-	-	-	*	-	-	-	-	-	-	Reportedly red ones rotate further. / Felt like room was moving
Participant 6	-	*	-	*	*	*	*	-	*	*	Reportedly didn't have to turn as much when it was scaled.
Participant 7	-	-	-	-	-	-	-	-	-	-	No comments
Participant 8	-	-	*	-	-	*	*	*	-	-	Reported scaled as being faster.
Participant 9	-	*	*	-	*	*	*	*	*	*	Scaled needed less movement
Participant 10	-	-	-	*	-	-	-	-	-	-	Room felt spinny
NEGATIVE	0.02	0.04	0.06	0.08	0.1	0.12	0.14	0.16	0.18	0.2	
Participant 1	-	*	-	*	*	*	*	*	*	*	Scaled reported to require more neck stretch or the angle was greater.
Participant 2	-	-	*	*	*	*	*	*	*	*	Scaled reported to be more difficult, feels like neck stretches more
Participant 3	-	*	-	*	-	*	*	*	*	*	Scaled needed more movement.
Participant 4	*	-	-	*	-	*	*	*	*	*	Sclaed movement: targets seemed farther away
Participant 5	-	-	-	-	-	-	-	-	-	-	Felt different at -0.04, but does not know why
Participant 6	*	*	*	*	*	*	*	*	*	*	Move more for scaled / move less for unscaled reportedly.
Participant 7	-	-	-	*	*	*	*	*	*	*	Move more for scaled / move less for unscaled reportedly. (again)
Participant 8	-	-	-	-	-	-	-	-	-	-	Only thing they noticed was the thing being jittery
Participant 9	-	*	*	*	*	*	*	*	*	*	Scaled movement needed more effort/movement
Participant 10	-	-	-	-	-	*	-	-	-	-	Distance felt slightly longer on that one.

Figure B.11: Combined table showing when scaling was correctly identified with general comments

C. Appendix A

- Audio-Visual Production.
- Results from the movement experiment.
- The code.
- The MedCon poster.
- Two state of the art tables, which are part of a graded assignment for the course Foundation in Medialogy.