A comparaison protocol of kinematics and macro movements in Virtual Reality and the Real world

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Abstract. Already a few studies have proposed protocols and experimentations to compare tasks in the Real World and in Virtual Reality but a lot of them are dating back from before 2010 and are using old equipment such as CRT monitors with stereoscopic glasses, or are only implementing basic tasks such as pointing an object.
In this paper, we are proposing a new protocol to compare the achievement of a complex task in Virtual Reality and in the Real World. For the virtual reality we are using one of the most recent consumer accessible virtual headset, the Oculus Quest 2 and data from real world's task is gathered using a full body motion capture device, the Perception Neuron Pro. We then standardize data from Real World and Virtual Reality to be able compare them by execution time, maximum acceleration, order of execution.

1 Introduction

Virtual reality has multiple research applications in scientific fields, one of them is in psychology, to evaluate sensory, motricity and cognitive functions. LS2N laboratory of Nantes University has partnered with psychiatrists and psychologists to develop different virtual environments, tools and methods to help better diagnose mental disorders. One of those tools is a generic environment in virtual reality in Unity developed by Polytech students Paul Blanloeil and Ioan Savoiu. It allows experts to easily set up a number of tasks, called a scenario, that a subject will have to perform. It let's the experts create experiments and automatically collect data without having to create and build real props or environments. During the tasks, the virtual reality controllers positional and input data are being recorded, giving precise measures of the subject's movements and strategy. However, the validation of the movements in virtual reality compared to a movement in reality in similar context is important. The virtual reality induce a number of chances that might impact the subject's interactions during the task. Their micro-movements might be different because of the lack of physical contact with objects, or because of the controllers being constantly held in both hands and headset on the head. Their macro-movement and general strategy might also be different because of the 3D rendered world surrounding them.

These impacts have to be taken in consideration before an analysis is made. In this paper, we present our approach to creating a protocol to compare and evaluate kinematics and macro movements in Virtual Reality and in Reality.

2 State of the art

2.1 Virtual Reality

Virtual Reality (VR) is a visual technology aimed at replicating the effect of visual depth and perspective in a virtual world. It is most usually used with a dedicated interface, a head mounted display, and one or two hand controller that are tracked in space to replicate the user's actions in the virtual world.

2.2 Previous research

A few articles have already described the differences between a task in virtual reality and in the real world but only partially. First, in "Reaching in reality and virtual reality: a comparison of movement kinematics in healthy subjects and in adults with hemiparesis" [1] from 2004, the task is only a reaching task and therefore not a complex task and is dating back from 2004. This article shows a slight difference in time and wrist extension that could be explained by the lack of perceived depth and the haptic feedback. A second article from 2009, "Comparing Aimed Movements in the Real World and in Virtual Reality" [2] shows that for rapid aimed movement, a subject in Virtual Reality takes 6 times as long as they would in the Real World to correct their movement. Even though this article is interesting regarding the data analysis, can still be referred as a simple task. Lastly, the article "A protocol for the comparison of reaching gesture kinematics in physical versus immersive virtual reality" [3] from 2020, is much more promising, because it compares trajectories with a complex task that is picking up items at a supermarket, but there is no analysis of the solving process by the subject.

Because none of the previous studies are working on the comparison between Virtual Reality and Real World for a complex task by analysing a task where a problem has to be solved, we believe that our experiment has reasons to be conducted.

3 The exeperiment

The study takes place in two similar worlds, one in a virtual world (VW), using the Oculus Quest 2 (OQ) and one in the real world (RW) using the Perception Neutron Pro (PNP).

For each world, the subject has to solve a complex randomized task, first, he performs 10 practice trials, 5 recorded trials are then done, the task's details being randomized each time, and lastly, 5 recorded trials are done, but with the task's details not being randomized with none colored cubes. Each subject's first environment should be randomized, so no bias for one of the two might be found in the data.

The goal of this experiment is to acquire all possible data form the subject's performance. We are interested in micro-movements such as the upper-body members trajectories during actions such as reaching and grabbing, and more macro-movements such as the strategy used for performing the task.

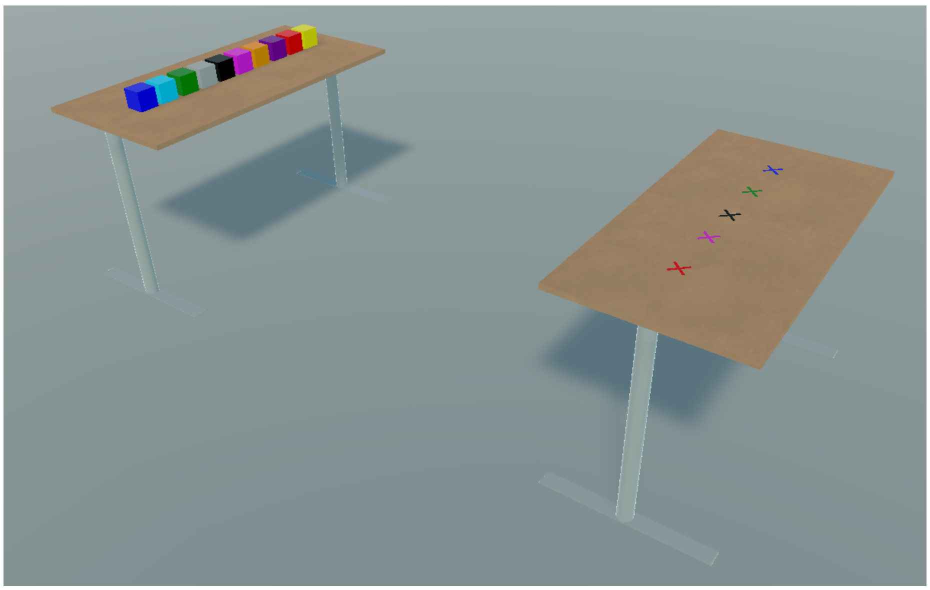

Fig. 1. The experiment set in Unity

3.1 The environment

The virtual reality world and the real world, are setup to be as identical as possible to ensure that the measured differences are not related to the setup. Each world is composed of a room with two tables facing each others with a distance of 2 meters. We don't want the tables to be to close to each others, in order to made sure that the subject can't use the two tables without moving.
On the first table (A), we place 10 cubes on a line in the center of the table, each cube being 10cm tall and each of different color. We choose the colors to be different enough, so that a subject with no color blindness could easily tell them apart.
On the second table (B) we place 5 markers on a line, each being the color of one of the cube. The color of the markers are also randomly selected at the beginning of each trial.

3.2 The task

Using the previously described environment, the task consists of placing the cubes from table A to the markers on table B according to their color. At the beginning, the subject starts in the center of the room, and the task ends when all cubes are placed on their corresponding markers. For the second set of 5 trials, the colors of the cubes are removed, to measure the variation of time to complete the task, when there is less reflexion.

3.3 The virtual world

For the virtual world, we are using the Oculus Quest 2 because it is one of the most widely used virtual reality headset and one of the most affordable and has been shown to have a better tracking system than the HTC Vive [4]. We are using a tool developed with the game engine Unity by students from Polytech that allowed us to create a scene corresponding to the previously described environment. For each trial in virtual reality, a csv file is created containing position and rotation data of the headset, the right hand and the left hand for each frame, with a sample frequency of 1/60Hz. A last file is saved containing each event regarding the grab or release of one of the cube.

3.4 The real world

For the real world, we are using the Perception Neuron Pro, a motion full body motion capture system that allows us to acquire data about the hands and head position, rotation velocity and acceleration with a sample frequency of 1/120Hz. Data can be saved using the Axis Neuron Pro software. The PNP is composed of sensors, one for each main part of the body (head, arms, forearms, hands, shoulders, back, etc) that are attached on the body with rubber bands. The sensor then communicate wirelessly to an antenna plugged in the computer running the Axis Neuron Pro software.

3.5 Subjects

For this study, 15 participants are chosen, because we only want to measure the differences between virtual and real, we choose to have only healthy subjects. Because the task heavily rely on colors recognition, only non-colorblind people should be selected.

4 Data pre-treatment

In order to be able to compare data from the motion capture and from the Oculus headset, we first have to transform data in the same format. Below is included the full transformations of the data from the Perception Neuron Pro or Oculus Quest 2 to the data analysis.

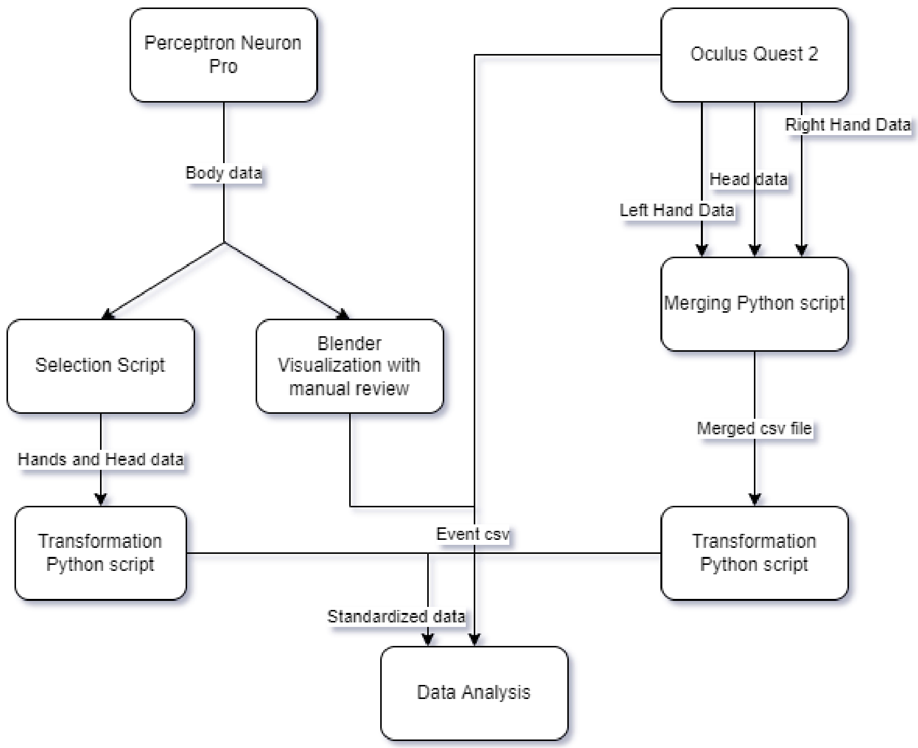

Fig. 2. Data path from the acquisition to the analysis

4.1 For the real world

For the data from the motion capture device, we first wrote a python script to visualize the data using Blender, using this visualisation and the video taken during the trial, we manually created a CSV file containing each event regarding box grasping and releasing that is in the same format as the one created by the Unity's tool. The event file will later be used during the analysis to splice the task into subtask.

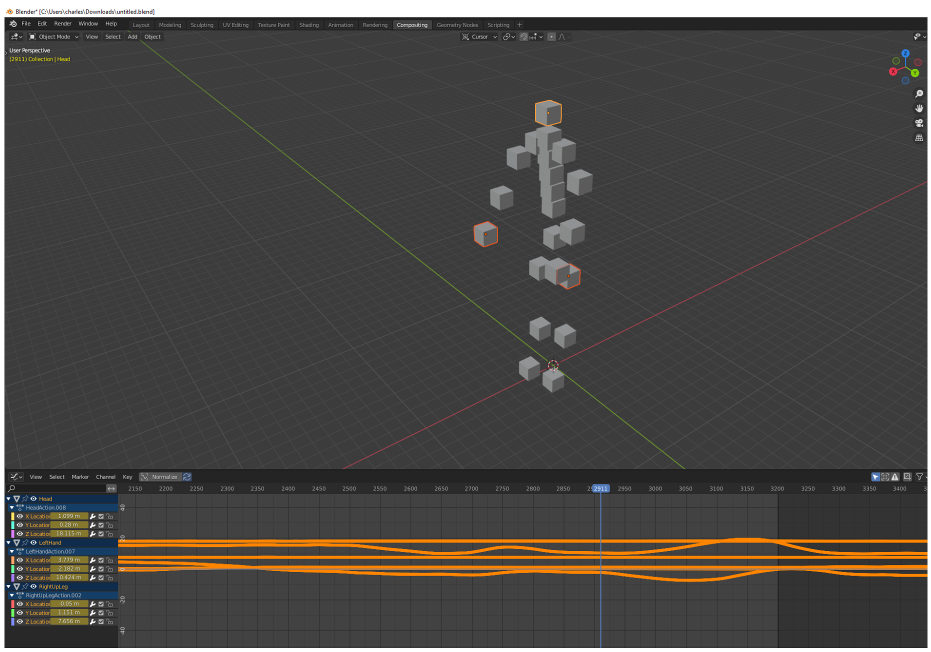

Fig. 3. Perception Neuron Pro data visualised using blender

We then with a python script create a file containing only the hands and head position, rotation, velocity and acceleration, centered around $x = 0, y = 0$ with the z axis pointing up, and used the feet z position to find the ground of the scene. This newly created file is the one that is going to be later used for the data analysis.

4.2 For the virtual world

For the data acquired with the Oculus in virtual reality, we first merge the three file containing the coordinates of hands and head into one single file. We then compute the velocity and acceleration of each hands and for the head by using the following formula for each $A \in x, y, z$ component $VelocityA_t = \frac{A_{t+1} - A_t}{\Delta_t}$

$AccelerationA_t = \frac{VelocityA_{t+1} - VelocityA_t}{\Delta_t}$, then we export the computed data in a csv file containing the position, rotation, velocity and acceleration of both hands and the hand, with the same format as for the real world.

4.3 Results of data pre-treatment

Once data of both Real World and Virtual Reality has been centered and standardized to be the same format, we recorded movement using both the VR headset and the motion capture suit to verify that the coordinate system and units were the same. In the future, a more rigorous way of verifying the results could be used by for example, computing the mean difference on x,y and z axis between the Oculus and the Perceptron.

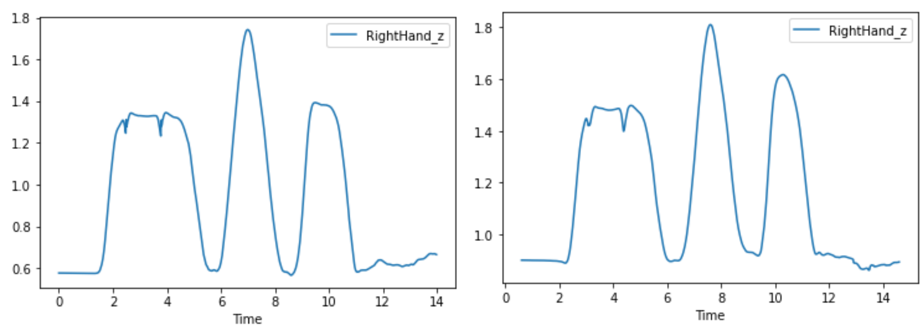

Fig. 4. Right Hand height measured using the Oculus Quest 2 on the left and the Perception Neuron Pro on the right

5 Data analysis

To study the differences between Virtual World and Real World, we decided to have three angles of analysis, the first one about the movement during the task such as the maximum acceleration per sub task. The second about the time duration, and lastly we are going to analyse the differences in the process of solving the task.

5.1 Time analysis

First, we compare the mean time taken to complete the task by all the subjects in Virtual Reality and Real World to have a first overview. We the split the task into 3 types of sub task:

- Grabbing, when the subject is grabbing a box.

- Releasing, when the subject is releasing a box.
- Moving, when the subject is moving from a table to another.

To split these sub task, we are using the event file which describe when a cube has been grabbed or released, and to decided when to split before an event, we are looking at the closest significant acceleration of the grabbing or releasing hand before the event, meaning the beginning of the movement toward the cube. Once the task has been split, we compute the mean time take for each sub task for all the subject and compare it between Real World and Virtual World.

5.2 Movement analysis

First, we compare the mean distance traveled for all the trials. We then use the sub tasks computed during the Time analysis and use them to compute the mean distance traveled and maximum velocity for each type of task. To compute the mean distance traveled we use the head position. We then compute the mean distance traveled and maximum velocity for all the trials end per sub tasks but this time using hands position. Once those data computed, we can compare them between Virtual Reality and Real World.

5.3 Solving process analysis

First to compare Real World and Virtual Reality we are going to compare the ratio in execution time as $\frac{Time(RealWorld_{coloredcubes})}{RealWorld_{noncoloredcubes}}$ and $\frac{Time(VirtualReality_{coloredcubes})}{VirtualReality_{noncoloredcubes}}$ to verify that the thought process has indeed a significant impact on the execution time. If there is an impact, we are then going to compare the average execution time between Real World and Virtual Reality by computing $\frac{Time(RealWorld_{coloredcubes})-RealWorld_{noncoloredcubes}}{Time(VirtualReality_{coloredcubes}-VirtualReality_{noncoloredcubes}}$. If the thought process is taking a higher time in Virtual Reality, we should see a result higher than one.

6 Expected results

As seen in previous experiments, we expect the macro and micro movements to be slower in Virtual Reality but this could be mitigated by the better depth perception and immersion provided by the Oculus Quest 2 compared to older devices. As for the comparison in the solving process, we do not expect statistically significant differences because the tasks are identical and the Virtual Reality should not change the thought process.

7 Conclusion

This project's initial goal was to evaluate the ecological situation of the Virtual Reality tool used for psychometric analysis. During our research, we learned that not many experiment took in both micro and macro movements to evaluate the impact of a Virtual Reality system. With our experiment and protocol, a rigorous analysis of the impact on a subject's performances can be done. The Polytech student's tool can now be used in a number of psychometric analysis without have to compare with real world data. Some possible future work could consist in automating the protocol in the Virtual Reality Tool, and generating some complementary information to make the data analysis easier. Some additional experiments can also be done with other capture systems, and other Virtual Reality controllers, to generalize the comparison between the VR and RW, not only between the two current systems.

All scripts used for the data processing and data analysis are available on our Gitlab https://gitlab.univ-nantes.fr/E200612G/ter_psycho.

8 Acknowledgment

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