The difference in speed and accuracy between using controllers and hand tracking in a VR pick-up-and-place interaction.

Chris Huider

Amsterdam University of Applied Sciences

Abstract

When using virtual reality (VR), as a player, you've got two choices of how you interact with the virtual world. On the one hand, you have controllers, on the other hand, you have hand tracking. This brings forth the question: "Which of these two interaction types is better?".

The question of which of the two interaction types, controllers or hand tracking, is better, redefined into a more researchable format: "What are the differences between the interaction types: controllers and hand tracking; when it comes to speed and accuracy of interactions?" will be examined by conducting an experiment where the participant must pick up and place a mug in a specific location repeatedly as fast as possible within a set time frame.

My hypothesis is that controllers outperform hand tracking in both categories: speed and accuracy; in every way.

The results show controllers only outperforming hand tracking in speed and two out of three accuracy categories. While hand tracking outperforms controllers in one of the three accuracy categories.

Using these results I can refute my hypothesis of controllers outperforming hand tracking in both the speed and accuracy categories.

Keywords: virtual reality; hand tracking; meta quest; interaction; speed; accuracy

1. Introduction

When using VR, as a player, you've got two choices of how you interact with the virtual world. On the one hand, you have controllers, which give you something tangible to interact with and can be used in many ways, on the other hand, you have hand tracking, which will give increased immersion by placing your own hands in the virtual world. This also brings forth the question: "Which of these two interaction types is better?".

The choice between controllers and hand tracking can have different outcomes based on what the player must do while in the virtual world, factors like the number of different interactions, ease of use, ease of learning and many more can influence this choice. When making this choice, one may think of what they're sacrificing by choosing the one over the other, seeing as both have their own strengths and weaknesses.

In this research paper two of such strengths/weaknesses will be covered, namely speed and accuracy of interactions.

This will be done by conducting an experiment where the participant must pick up and place a mug in a specific location repeatedly as fast as possible within a set time frame. They will first have a practice go at the experiment for both the controller and hand tracking interactions, after which they will have to complete the experiment with both interaction types a single time without redoes.

During the experiment, the program will keep track of data on the speed of each interaction and accuracy at which the mug is placed close to the designated location. In the end the data will be analyzed, and a conclusion will be drawn as to whether controllers or hand tracking is faster or more accurate, or both.

2. Research question

As previously introduced in the Introduction, the question of which of the two interaction types, controllers or hand tracking, is better, is what led to this research paper, but in order to constrain this question into a more researchable format the question was reformulated to:

“What are the differences between the interaction types: controllers and hand tracking; when it comes to speed and accuracy of interactions?”

This question will be answered by the end of this research paper.

My hypothesis is that controllers outperform hand tracking in both categories: speed and accuracy; in every way.

3. Related works

The performance and immersion have been compared between controllers and hand tracking in previous studies.

One such study aimed to answer the overarching question which led to my own research question. They believed that hand tracking enables controller-free interaction with virtual environments, which can, compared to traditional handheld controllers, make virtual reality (VR) experiences more natural and immersive [1].

In order to find out if this was true, they examined the grab-and-place task whose performance was analyzed in terms of accuracy, speed and errors as well as subjective experience by comparing a prototype of a camera-based hand tracking interface (Leap Motion) with customized design elements to the standard Leap Motion application programming interface (API) and a traditional controller solution (Oculus Touch). [1].

Another study aimed to investigate the differences between using VR controllers and hand tracking in medical interactions [2].

They developed a VR intubation training as a case study and applied controllers and hand tracking for four interactions—namely collision, grabbing, pressing, and release [2].

4. Experiment

This section will dive into the conducted experiment, metrics, constraints, and any other details related to the experiment or its test subjects.

4.1 Environment

This experiment is conducted in a virtual world, built in Unity (version: 2023.1.14f1) [3] using the Oculus Integration package [4] and visualized using the Meta (formerly Oculus) Quest 2 and Meta Quest Pro [5].

Disclaimer: Even though the results were gathered using both the Quest 2 and Quest Pro, no distinction between them will be made.

4.2 Setup

The participant is seated and transported to the virtual world where they find themselves in a living room. In front of them is a table with a red button and a time indicator.

The participant will receive an explanation where they’re told what the experiment entails and what they have to do. They then have to do two practice runs of the experiment, one time using the controllers and one time using hand tracking.

The experiment itself starts by pressing the red button, after which it will disappear and a mug and a blue indication circle will appear. From this point on the timer will count down from 15 seconds and the participant has to place the mug in the specified location, which is indicated by the blue indication circle. When they do, the circle will change locations a fixed distance from its previous location. They have to move the mug to the specified location as many times as possible before the time runs out, after which the participant can see their score and all of the collected data will be compiled into a text document for later use.

Once they have familiarized themselves with the experiment, they have to complete the experiment two times once again, one time using the controllers and one time using hand tracking. These two runs of the experiment will collect the data which will be used in the results.

4.3 Participants

Participants are selected from the students of the virtual reality minor of the Amsterdam University of Applied Sciences without accounting for gender. They are all familiar with virtual reality using controllers, but only some are familiar with hand tracking and some aren’t, so a distinction will be made between these two groups when looking at their results. None of the participants were paid for their participation and all of them received only an explanation of what to do and not what metrics would be used during the experiment.

4.4 Metrics

Data will be collected during each of the two non-practice runs of the experiment. During these runs data on interaction type, placing proximity distance, maximum allowed distance and correctness, interaction-, non-interaction time and amount of interactions with the mug and the total experiment time, is collected.
These data points will be used in the following metrics:

- Proximity correct placement percentage

- Times the mug was placed within proximity = x
- Times the mug was interacted with = y
  [value = (x / y) * 100]

- Proximity incorrect placement percentage
  - Times the mug was placed outside proximity = x
  - Times the mug was interacted with = y
    [value = (x / y) * 100]

- Proximity correct distance percentage
  - Sum of proximity distance every time the mug was placed within proximity = x
  - Times the mug was placed within proximity = y
  - Maximum accepted correct distance = z
    [x = distance1 + distance2 + distance3 + etc...]
    [value = (x / y) / z]

- Interaction time percentage
  - Sum of every interaction time = x
  - Total experiment time = y
    [x = interactiontime1 + interactiontime2 + interactiontime3 + etc...]
    [value = (x / y) * 100]

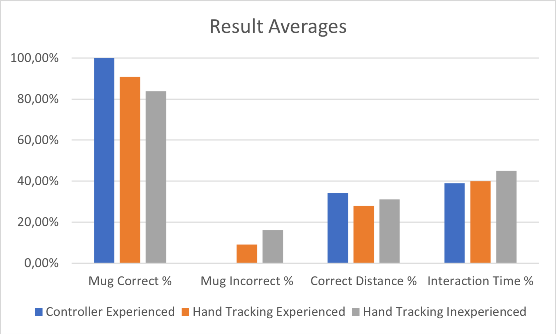
5. Results

This section will dive into the results gathered from the conducted experiments, its analysis and any other details related to the experiment's results.

5.1 Collected Data

The data, which was collected during the two non-practise runs of the experiment, collected from six participants was all compiled into an excel sheet, which you can find as Appendix 1.

From this data sheet, the following graph could be made, containing the average percentages of the metrics, categorized in the three categories: Controller experienced, Hand tracking experienced and Hand tracking inexperienced.



For this graph, the following details are important. The following metrics apply: "Mug Correct %" - higher is better, "Mug Incorrect % - lower is better, "Correct Distance % - lower is better, and "Interaction Time % - lower is better.

5.2 Analysis

When looking at these results, starting at the "Mug Correct %", which entails how often the mug was placed within the boundary of the specified location, we can see the controller performs better than hand tracking, both experienced and inexperienced. Between them, experienced outperforms inexperienced. This is the same for the "Mug Incorrect %", which entails how many times the participant placed the mug outside the boundary of the specified location or dropped the mug, where we can see the controller performing better than hand tracking, both experienced and inexperienced and between them experienced outperforms inexperienced again.

When looking at "Correct Distance %", which entails accuracy when placed within the boundary of the specified location, we see hand tracking performing better for both experienced and inexperienced. Between them, experienced does perform better than inexperienced.

Finally looking at "Interaction Time %", which entails the percentage of interaction time during the experiment, we see the controller performs better than hand tracking, both experienced and inexperienced. Between them, experienced outperforms inexperienced.

5.3 Discussion

Controllers outperformed hand tracking in three out of the four categories. "Mug Correct%", "Mug Incorrect %" and "Interaction Time %" all saw controllers outperform hand tracking, both experienced and inexperienced, where between them experienced outperformed inexperienced.

For "Correct Distance %" hand tracking, both experienced and inexperienced outperformed controllers, where between them experienced outperformed inexperienced.

6. Conclusion

The results show controllers only outperforming hand tracking in speed and two out of three accuracy categories. While hand tracking outperforms controllers in one of the three accuracy categories.

Using these results I can refute my hypothesis of controllers outperforming hand tracking in both the speed and accuracy categories.

7. Future work

This experiment was focussed on analyzing two strengths/weaknesses of controllers and hand tracking, namely speed and accuracy of during a pick-up-and-place interaction with a mug with a small number of participants.

In future works the entirety of the differences between controllers and hand tracking could be explored. As stated in the Introduction, many more points can be explored, like the number of different interactions, ease of use, ease of learning and many more. Seeing how these points have an effect upon the results could prove valuable.

Also conducting this experiment with a broader range of participants with more differences in age and experience in using VR might have an impact on the outcome of the result, worthy of being explored.

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Appendices

1. Results data sheet

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