20 Ways to Answer Binary Questions in VR

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ABSTRACT

There is a multitude of ways developers can allow users to interact with their Virtual Reality (VR) applications to accomplish the same task - such as answering binary questions. However, such variety coupled with a lack of comparative studies, makes it hard to infer which technique works best. As such, we designed an experience to compare 20 different interaction techniques directed towards answering binary questions. Alongside this we created a set of forms for users to state their preference and opinions regarding their tested techniques. With this, we were able to formulate proper documentation for each of the techniques, including information such as overall popularity and enjoyment amongst users. Furthermore, we will also be able to conclude which control paradigm - controllers, hands or head - users find more appealing for our specific task. This work and its results could then be further analyzed and expanded through the addition of new scenarios, different tasks or new interaction methods.

1 INTRODUCTION

One of the key factors influencing a user's enjoyment of a Virtual Reality (VR) experience is how they interact with it. Due to the nature of these applications, there is a multitude of ways designers can allow users to accomplish the same given task. However, such variety, coupled with the lack of standardization and studies comparing interaction methods, can be a crux. Given too much freedom of choice, and little insight on what users actually prefer, developers may end up implementing interaction methods that are uncomfortable or inappropriate for the task.

A common task present in many VR applications is the answering of binary questions, for example, to interact and converse with Non-Playable Characters (NPCs). The task's triviality lends itself well to being accomplishable in many ways, from conventional controller A/B buttons, to Hand gestures or even Head motions. We believe that by creating an experience which allows users to go about the same scenario in which their only task is to answer "Yes" or "No" questions, utilizing different interaction techniques will allow us to perform a formal comparative study on which techniques are preferred. With the insight gained from such a study, designers will be able to discern the advantages and disadvantages of each interaction technique and select which is most apt for the specific scenario and environment they place their users to answer binary questions in.

Our work is based on the efforts of Zhao & Allison [6]. In their own work they placed users into VR scenario in which they were tasked with memorizing the objects placed in a shelf in front of them. Afterwards the object would disappear from the shelf and users would be asked if the currently shown object was part of the original set. Users would answer using one of 3 different interaction



Figure 1: Our 3 paradigm categories and all 20 of our interaction techniques. *Controller* techniques require the user to interact with a physical Oculus Touch Controller, *Hands* techniques require no extra controllers instead relying on hand detection and recognition algorithms and *Other* techniques include both Head-based interactions and techniques which combine Head and Controllers or Head and Hands

methods: A Gamepad's bumper buttons, Hand Gestures ("Ok" symbol for "yes", open hand for "no") or Head Gestures (nodding for "yes", shaking for "no"). The metrics extrapolated for comparison were both subjective and objective. For the latter they analyzed the Response Time (delay between question and user answer) and Real-Time Accuracy (users' performance in the memorization task). For the former they evaluated Ease of Learning, Ease of Use, Natural to Use, Fun, Tiredness, Responsiveness and Subjective Accuracy using a user questionnaire.

We have further expanded upon this work by upping the total amount of interaction techniques from 3 to 20. Furthermore, we opted against using a memorization task, since we believe that it added an unnecessary overhead unto the users, forcing them to focus more on the task, rather than the interaction. Instead, we created an interactive scenario in which the user converses with NPCs, who continuously ask the user Yes/No questions with no correct answer. We believe this setting to be more apt since the task requires less of the user's attention, allowing them to focus more on the interactions. Alongside this, and as aforementioned, conversing and interacting with NPCs, specifically to answer questions posed by them, is a common task in many VR applications and video-games, making it a more common presentation of binary question answering compared.

2 METHODOLOGY

2.1 Interaction Techniques

Within our experience, users were allowed to choose between 20 different techniques to answer binary question. These techniques were broken down into three main categories referring to their control paradigm - Controllers or Bare Hands. The **Other** category includes techniques which rely on Head-based interactions, or combinations of Head plus Hands or Controllers. Figure 1 presents all 20 of our interaction techniques.

Our techniques range from simple Controller A/B buttons, to Hand Gestures (Thumbs Up/Down) implemented through a simi-

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Figure 2: Our main menu (left) and example of a technique's instructions scene (right). The main menu allows the user to pick which interaction technique they will be using, with them being organized under their respective categories so as to not overload the user with too many options. As for the instructions we show a description of the technique and exemplify how to use the technique with illustrative images.

larity algorithm that compares the tracked hand's bones' position and orientation relative to palm [4] and even Head Nodding/Shaking making usage of the Head Mounted Display's (HMD) accelerometer. Besides more conventional techniques we also have a few novel ones such as using a swiping motion, interacting with the environment by physically pushing down buttons placed in front of the user at an adjustable height [3] or headbutting targets placed near the user's head. A full list and description of the available techniques can be found in Appendix A.

In terms of menu control, the user can interact by pointing and confirming using the controller's index triggers or A buttons. The same applies for scenes that utilize controllers. For those that use Hands instead, the user can interact by pointing and pinching. During the main task scenario, the user can also bring up an options menu by either pressing down the Oculus Touch controller joysticks, when using the Controller interaction techniques, or performing a "horns" gesture with the hands, when using Hand based interaction techniques.

2.2 User Interfaces

Our user interface depends on the scene the user is in. For the main menu and the instruction scenes, we created a diegetic interface by having the menu displayed on a projection screen, coming from a projector placed on the room's ceiling. These interfaces consist of either a checkbox list, displaying all interaction techniques for the user to choose from, broken into the aforementioned categories, or text and images showing the user how to utilize the chosen technique.

During the actual scenario, our User Interface (UI) consists of the NPCs' subtitles, displayed under them in a white font with a black outline, to make it discernible from the environment, and the question prompts which consist of two icons which show up next to the NPC who placed the question. Depending on the chosen interaction technique these prompts may serve as buttons, highlighting when pointed at, or filling up gradually. Certain techniques also warranted the addition of other interfaces and visual aids, such as the trail created on the swipe style interactions, the 3D buzzers, boxes, grabbable cube and headbutt-able spheres, the placement of which is based on the user's height, so as to make the process more comfortable. The user can also bring up an options menu allowing them to return to the main menu or reset the height of interactable objects, when applicable. When answering, the user is given audio cues and haptic-feedback in the form of controller vibration. Figure 3 showcases some of the aforementioned interface elements, notably the aforementioned question prompts, grabbable cube and boxes and the options menu.

2.3 Apparatus

Our application was built to run natively on the **Oculus Quest 2** Head-Mounted Display (HMD) using the Unity Engine and the official Oculus Integration Package. It also works on the original Oculus



Figure 3: The NPC's subtitles and the question prompt (top left), the Grab and Drop interactible objects (top right) and the options menu (bottom). The question prompt highlights when hovered in order to indicate that they can be interacted with. The grabbable box on the second image enables a white outline when it can be grabbed. As for the options menu, it allows a user to exit the scene before it ends, or reset the height of intractable objects in the environment, notably the buttons and grabbable cube/boxes.



Figure 4: Example of a question being posed by one of the Non-Playable Characters (NPCs). In this particular example the NPC is asking the user "How are you doing? Good I hope?", to which the user can then respond "Yes (I'm doing good)" or "No (I'm not doing good)".

Quest HMD, albeit at a lower frame-rate, hindering the overall performance of the application. For certain interaction techniques we require the usage of the Oculus Touch controllers, whilst others make usage of the Oculus Hand Tracking feature, which needs to have been enabled in the device's settings before running the application.

2.4 Tasks

To reiterate, the goal of our experiment was to compare the interaction techniques for binary answering. We aimed to avoid any unnecessary noise and variables so as to allow users to focus on the techniques themselves and how appropriate they were for the task, rather than shifting their attention to the task itself. As such, the task we devised had the user, when prompted, answer the question posed by an NPC using the currently selected technique. The posed questions were always "Yes"/"No" questions and there was no correct answer. Different answers had the NPC reacting differently, simulating what an actual conversation would be like in a social party setting. As aforementioned, this task also had the benefit of being a common application of binary question answering in VR applications, specifically video-games, adding to the generality of the gathered data. Figure 4 showcases one of the questions the NPC poses during their dialogue, particularly, exemplified is the first question the user is asked.



Figure 5: Our 4 scenes. The user begins in the main menu (top left), then, after picking an interaction, goes to the instructions scene (top right). They then move on to the main scene (bottom right), and when this ends, they are brought to a thank you scene (bottom left). From there, they can repeat the process by going back to the main menu

2.5 Procedure

Figure 5 showcases our four main scenes, and how the user transitions between them during the experiment. Users begin by being placed in a room where they may select which interaction technique to use - the main menu. After selecting their wished technique and confirming, they are taken to an instruction room which explains how to answer questions using the selected technique. They may proceed to the following scene whenever they're ready by pressing the "Start" button. At that point they are taken to the main scenario. Users are placed into a living room with several NPCs within a party setting. They are greeted by the party's host, who begins conversing with the user asking binary questions such as "How are you doing? Good, I hope?", and "Have you tried the food yet?", which the users can then answer using their chosen interaction technique. After a while a new NPC, one of the party's guests, walks over and interjects the conversation. The user then converses with this guest until the conversation ends. When this happens the screen fades to black and the user is taken to a new room thanking them for having participated in the experience, and instructing them to fill out our set of forms. The user then returns to the main menu and can choose to try out a different interaction technique, or exit the application. The user can, at any given point in time during the main scene, bring up an options menu and exit the scene back to the main menu.

3 USER TESTING

Our work focuses on evaluating subjective metrics, similar to those in the paper that inspired our work [6] - *Ease-to-Learn, Ease-to-Use, Natural-to-Use, Fun, Tiredness, Responsiveness* - alongside new metrics pertaining to *Cybersickness* - relevant due to our Headrelated answering techniques - and *Presence*. We believe analyzing these metrics in particular will yield insight as to which interaction technique users find more endearing for answering binary questions.

With this in mind we constructed a set of forms composed of a *Demographic Profile Form*, a *User Satisfaction Preference Questionnaire*, Witmer, Jerome, Singer's 29-*item Presence Questionnaire* (PQ Version 3) [5], *NASA Task Load Index* [1] and the *Interaction Technique Usability Scale* (a reduced version of the System Usability Scale [2] aimed at our interaction techniques).

These questionnaires not only take into account the user's overall experience with VR applications and, more specifically, the task of answering binary questions in VR environments, but also certain biological factors such as their height, which become relevant when analyzing interaction techniques which require them to pick up or interact with objects placed in the environment. They focus on



Figure 6: The demographic profile of our user study participants. On the top left we can see that most of our participants are male, with a single female participant. On the top right we can see the ages of each of our participants, with our youngest participant being 21, 2 being 24 and our oldest 2 being 54. The bottom left graph indicates that 2 of our participants have no previous experience in VR whilst the remaining are fairly accustomed to it. However, and as seen on the bottom right graph, only 1 of our experienced VR participants has answered binary questions in VR before. These graphs were automatically generated by Google Forms.

ascertaining the user's overall enjoyment of their chosen interaction technique, any adverse effects such as tiredness or nausea, and how well the method correlated with our conversation setting, alongside the aforementioned metrics.

A small supervised study was conducted online, with a select group of volunteers. In order to avoid the order in which participants tried out each interaction technique influencing their opinions we conducted a "Between-Subjects" study, in which each participant was assigned a randomly selected interaction technique, from amongst the 20 available. In total, and as seen in Figure 6, we had **6 participants**, 5 of which were male and 1 female. Their ages could be grouped into two bins, with 3 participants being in their early 20s and 2 being in their early 50s. Experience-wise, 4 of our participants had some modicum of experience with VR, whilst 2 being completely new to it. Despite this, of those with prior VR experience, only 1 participant reported having answering binary questions in a VR environment before.

Due to our reduced number of participants, only 6 techniques were able to be tested, each with only 1 participant. The selected techniques were Controllers A/B Buttons, Controllers Trigger Swipe, Hands Gestures, Hands 3D Buzzers, Head Tilt and Headbutt. These techniques were specifically chosen by taking into account prior informal tests conducted during the creation of the experiment. These "quick and dirty" pilot studies revealed that users tended to prefer techniques that did not require much effort to perform, notably the Controller A/B Buttons and Controller Trigger and Swipe. Hand based techniques, especially Hands Gestures and Hands 3D Buzzers, garnered a lot of early attention due to the novelty of interacting within a VR environment without needing a physical controller, whilst Head-based techniques seemed to induce some minor levels of cybersickness, especially Headbutt and Head Tilt which was also reported as causing some neck strain. These 6 techniques were therefore chosen, not only to infer their own usability, but also as representatives of each of their corresponding control paradigms.

4 RESULTS AND DISCUSSION

Firstly, referring to our User Satisfaction and Preference Questionnaire, we started by asking users questions relating to their overall perception of the overall scenario and task they were presented with, in order to infer if there were any inconsistencies caused by their



Figure 7: Answers to questions about the user's overall opinion on the setting and task. On the top left we can see that all users had the same overall appreciation for the environment's aesthetics and looks. On the top right we can see that everyone was more or less able to clearly understand the NPC's questions at the same level. On the bottom left we can again see that everyone was able to perceive the subtitles in the same way, with no one reporting any particular obscurity or hardship. On the bottom right we can see that, despite the interaction technique, everyone was able to understand when they were being prompted to answer a question. These graphs were automatically generated by Google Forms.

chosen interaction technique. However, and as seen in Figure 7, there did not seem to be anything of note, as all answers relating to these questions were pretty similar, regardless of the interaction technique.

Analysing the answers posed on the same form to questions related to the interaction technique itself, we can start seeing some wider deviation of results. In terms of overall enjoyment, and as can be seen in Figure 8, Headbutt scored the least, followed by Controller A/B buttons. The first can be explained by looking at the answers given to questions regarding discomfort, tiredness and difficulty to perform, as Headbutt ranked the highest (and therefore worst) in each of these categories. The participant specifically denoted a feeling of tiredness after their performance of the task. However, the same does not apply for the latter - Controller A/B buttons. This interaction technique ranked highly on ease of use, ease of learn and the participant did not report any nausea, tiredness or any other discomfort. As such, we believe that, whilst Controller A/B buttons is easy and comfortable to perform, it is not a fun way to answer questions in this type of setting, hence hindering the participant's overall enjoyment of the technique.

Figure 9 showcases that, overall, all techniques were easy to learn and, aside from *Headbutt*, easy to perform. However, both headbased techniques were reported as causing the most discomfort, both in terms of nausea and tiredness, validating the results obtained from our pilot studies. Furthermore, the participant performing *Head Tilt* specifically stated feeling some slight neck strain after the first round of questions.

As for accuracy and technical problems, the most unreliable interaction technique was *Hand Gestures*, having been the only one with a reported wrong detection (the participant wanted to answer "Yes", but the system detected "No") and, according to the participants, the slowest one to detect the answers with. However it should be noted that no interaction technique caused the participant to answer when they did not intend to. This can be seen in figure 10, which shows the graphs related to the accuracy performance of each interaction technique.

Moving on to the **29-item Presence Questionnaire** we were able to extract some conclusions mostly related to the interaction technique's impact on the user's feeling of presence. Looking at the provided answers for the question "Were there moments during the virtual environment experience when you felt completely focused on the task or environment" we were able to infer that Head Tilt,

Interaction Technique Enjoyment



Figure 8: Answers to questions about the user's overall enjoyment of their chosen interaction technique. As can bee seen on the graph, A/B buttons and Headbutt scored the least out of our 6 techniques. Enjoyment was rated on a scale from 1 to 7 with 7 meaning "Enjoyed it a lot" and 1 meaning "Did not enjoy it".

followed by Hand Gestures were the techniques that most caused the participants to lose focus on the environment. For Head Tilt this can be attributed to the fact that the tilting motion, which caused a rotation of the participants perception of the environment, ended up being too distracting, compared to something like Headbutt which, despite also requiring Head movement, had the user answer by performing a simple nudge in the direction the head was facing, rather than a neck tilt, meaning the user's point of view was only slightly transformed, instead of being fully rotated. As for the Hand Gestures we believe the poor performance can be related to the techniques overall detection accuracy. Since the participant was required to enact a specific gesture and hold that pose for a second, we think this caused them to focus more so on performing the gesture, rather than being immersed in the environment. Another interesting question pertaining to presence is "How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?". Surprisingly, and despite the aforementioned results on the previous question, Hand Gestures did the best in this question. We believe this was due to the fact that this was due to the lack of a need to hold physical controllers. The same cannot be said for *Hand Buzzer*. which we think scored lower than the other interaction technique in its category due to the lack of feedback users had when hitting the button within the VR environment, causing their sense of presence to be broken. Both Head-based techniques scored low, possibly due to the fact that performing the required motions with the head reminded the participants that they were wearing a head mounted display, making the screen shift, or requiring some readjusting of the display, hence breaking their sense of presence. Meanwhile Controller-based techniques scored fairly high despite having the user physically hold a controller. This can be explained by the fact that, after an habituation period, and due to past experiences in VR by the users who tested these techniques, they end up forgetting they are holding controllers in the first place, hence not hindering their sense of presence. These results can be seen in figure 11.

Using the **NASA Task Load Index** we were able to infer the strain and complexity of each interaction technique, as perceived by the users. Overall, most techniques ranked similarly in questions pertaining to mental demand, incurred stress, ease of performance.



Figure 9: Answers to questions related to the user's comfort whilst performing the interaction technique alongside the technique's ease of use and ease of learn. On the top left we can see the ease of use of each technique, with Headbutt being the only one scoring lower than a 5. On the top right we have each technique's reported ease of learn, with each one having scored similarly high. The bottom graphs show the degree of nausea and tiredness (left and right respectively) users felt, with Head Based techniques scoring the worst in these categories. All graphs were scored on a scale from 1 to 7 with 1 meaning "very hard" or "did not feel" and 7 meaning "very easy" or "felt a lot" for the top and bottom graphs, respectively.

In terms of physical demand, however, the *Head-Based* interaction techniques scored the highest, alongside *Hand Gestures* due to requiring the user to physically raise their arms to perform the gesture. This can be seen in figure 12.

Finally our **Interaction Technique Usability Scale** form, being a reduced version of the *System Usability Form*, allowed us to validate our conclusions from the previous *User Satisfaction and Preference Questionnaire*. Whilst no new insight was gained from this questionnaire, it was nevertheless useful to see that responses given coincided with those from the aforementioned form, specifically those pertaining to the technique's ease of use, ease of learn, complexity and enjoyment.

To summarize, there was no clear winner amongst our tested interaction techniques, with each having their own advantages and disadvantages. Controller based techniques were the most middling, with neither being disliked or particularly liked above all others. They did not cause any stress or discomfort on users, had any detection problems or break the participant's feeling of presence at any time, but never the less they were also not considered the most enjoyable techniques to use. Head based techniques were not outright disliked by the participants that tried them, but despite this, and their overall reliability, they caused the most discomfort on users, be it in the form of neck strain, tiredness or slight nausea. Hand based techniques were some of the most enjoyed by the users, possibly due to their novelty, however Hand Gestures caused tiredness on users by forcing them to repetitively raise their arms to perform the answering gesture and had certain detection problems, being the slowest technique amongst our set. Hands 3D Buzzer did not suffer from this same ailment, however, due to a lack of feedback when physically pushing down a button in a VR environment without receiving any actual feedback did cause the participant to feel a break in their feeling of presence, as they were reminded that the button,



Figure 10: Answers to questions related to the interaction technique's performance and accuracy. The top left graph shows how quickly users reported their answers as being detected, ranging from 1 meaning "very slowly" to 7 meaning "very quickly". The top right graph shows that only one of the interaction techniques - Hand Gestures - detected an answer incorrectly. The bottom graph shows that no technique detected a user's answer without their intent.



Figure 11: Answers to two of the 29 questions from the 29-Item Presence Questionnaire. Each question is ranked on a scale from 1 to 7. On the left we have the answers to the question "Were there moments during the virtual environment experience when you felt completely focused on the task or environment", whilst on the right we have the answers to the question "How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?".

alongside the rest of the environment, were in fact, virtual.

5 CONCLUSION

We created a Virtual Reality application that aimed to directly compare 20 different interaction techniques against each other. These techniques were used as different ways for users to answer binary questions. More specifically, we proposed a scenario in which users would interact with Non-Playable Character's (NPCs) in a fluid conversation. At certain points users would be prompted to answer certain "Yes" or "No" (i.e binary) questions by the NPCs using the current interaction technique, selected amongst the available 20.

This, coupled with a set of forms and questionnaires, allowed us to conduct a user study and determine the advantages and disadvantages of each of the interaction techniques for our specific task. We were able to incur metrics pertaining to each of the technique's overall ease of use, ease of learning, overall enjoyment, fun, accuracy and answer detection alongside factors such as fatigue and tiredness, nausea, cybersickness and overall physical and mental demand. Furthermore we also studied the impacts each interaction technique had on the user's feeling of presence.

One possible drawback of our application is that there is no system to capture objective metrics such as "Time taken to answer" which



Figure 12: The reported physical demand of each task. This graph is graded on a scale from 1 to 21 with highest meaning "more demanding". Head Based techniques were reportedly the most physically demanding, followed by Hand based techniques and finally Controller based techniques being the least demanding.

might also have been good to analyze. Furthermore, due to pandemic and time constraints the conducted user study was only able to accrue the participation of 6 volunteers, leaving 14 techniques untested. We believe there would be merit to continuing this study and possibly adding even more interaction techniques for comparison.

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A INTERACTION TECHNIQUES

A.1 Controller Interaction Techniques

Following is a list of all implemented Controller-based Interaction Techniques, which make solemn usage of the *Oculus Touch* controllers:

- **A/B Buttons** Answer by pressing the A (right controller) or X (left controller) for "Yes", or B (right controller) or Y (left controller) for "No"
- **Point Trigger** Answer by aiming either controller at the chosen answer prompt to select and press down the controller's index trigger to confirm
- **Point Trigger with Delay** Answer by aiming either controller at the chosen answer prompt to select and pressing down and holding the controller's index trigger until a circle fills around the prompt to confirm
- Joysticks Answer by swiping either controller's joystick right to answer "Yes" or left to answer "No"

- Trigger Swipe Answer by holding down either controller's index trigger and swiping the controller right to answer "Yes" or left to answer "No"
- **3D Buzzer** Answer by using either controller to physically push down the 3D buzzer corresponding to the chosen answer
- **Grasp Drop** Answer by using either controller to physically pick up the "Answer Cube" using the controller's hand trigger and dropping it in the box corresponding to the chosen answer

A.2 Hand Interaction Techniques

Following is a list of all implemented Hand-based Interaction Techniques, which make solemn usage of the user's bare hands and the *Oculus Hand Tracking* feature:

- **Gestures** Answer by performing a "Thumbs Up" gesture for "Yes" or a "Thumbs Down" gesture for "No"
- **Index Pointing** Answer by aiming and holding a ray shot from either hand's index finger at the chosen answer prompt until a circle fills around the prompt to confirm
- **Open Hand Pointing** Answer by aiming and holding a ray shot from either hand's palm at the chosen answer prompt until a circle fills around the prompt to confirm
- **Pointing Pinching** Answer by aiming and holding a ray shot from either hand's palm at the chosen answer prompt to select and pinching the index and thumb fingers together to confirm
- Swipe Answer by swiping either hand right for "Yes" or left for "No"
- **3D Buzzer** Answer by using either hand to physically push down the 3D buzzer corresponding to the chosen answer
- **Grasp Drop** Answer by using either hand to physically pick up the "Answer Cube" by pinching it using the index and thumb fingers and dropping it in the box corresponding to the chosen answer

A.3 Other Interaction Techniques

Following is a list of all implemented Head-based Interaction Techniques and Head-Controller/Head-Hand combo techniques:

- Nodding/Shaking Answer by nodding the head for "Yes" or shaking the head for "No"
- Head Gaze Answer by facing the head towards the chosen answer prompt until a circle fills around the prompt to confirm
- Head Tilt Answer by tilting the head right and back to the center for "Yes" or left and back to the center for "No"
- **Headbutt** Answer by physically headbutting the target corresponding to the chosen answer
- Head Gaze Controller Trigger Answer by facing the head towards the chosen answer prompt to select and using either controller's index trigger to confirm
- Head Gaze Hand Pinch Answer by facing the head towards the chosen answer prompt to select and confirm by pinching either hand's index and thumb fingers together