Photo Source: Yichen Wang (Source)

Affordances in VR and AR

Why do people behave differently when using AR compared to VR?

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Abstract

A pilot study was conducted in order to gauge an understanding of different affordances and behavioural patterns between AR and VR. The pilot study involved an AR and a similar VR activity accompanied by an exit interview and demographic questions. We found that 2 of 5 participants stayed seated while the other 3 were mobile. Of those that were mobile, there was an obvious level of higher mobility for the AR activity.

Affordances in VR and AR

Why do people behave differently when using AR compared to VR?

Introduction

Both Augmented Reality (AR) and Virtual Reality (VR) are relatively new technologies which are becoming increasingly used in everyday and professional environments. Even with the increasing focus this popularity is lending them, little research has been done on the affordances of each of these technologies.

Augmented Reality describes a type of technology which allows people to make interactions in the real world, which have virtual effects. Often virtual elements are overlaid on top of a users real environment. Virtual reality on the other hand completely replaces the surroundings of the user, immersing them in a completely artificial environment.

Affordances are defined as clues that help users intuitively understand how to interact with an object. Every object has its own unique affordances, doors have handles, links have underlines, emergency buttons are coloured red -- these are the sort of things we want to discover for AR and VR headsets. When a user is presented with one of these, what do they initially want to do with it?

Understanding these questions of what someone is expected to do when they're presented with a VR or AR headset is important, it allows us to design new experiences in such a way that they come more naturally to new users. This informs our research question, as we attempt to find out why there's a commonly held belief that people behave differently when using AR and VR.

Rationale

Affordances are an important part of everyday life. They provide the hints we need to interact with the world around us. If consumers misread affordances they feel a sense of confusion, which is obviously not the impact intended by the product or what we want to create as UX designers. Figuring out the affordances of a new input technology is an important step in any HCI research looking at new methods of interaction, because the way humans interact with the world around them is based on this language of affordance. For technologies to be as effective as possible, a complete understanding of the technologies is required, and this includes affordances.

AR and VR have hugely grown in popularity recently, and are projected to grow even further. Yet even as we use these new tools for more and more different things, there hasn't been much research into the intrinsic affordances that these devices have. In order for us to properly make use of AR and VR as designers we need to understand their differences from the perspective of users, what they excel in, and when to use one instead of the other. Doing so will allow us to better understand how the users will interact with them and critique any design choices which may be ineffective. These tools have the potential to be the next big step in human computer interaction, so it’s important we properly consider them to ensure they’re the best they can possibly be.[1]

When all the affordances and human computer interaction factors are discovered in AR and VR and widely understood, it’ll open so many doors for the future of these technologies that could otherwise be out of reach.

Due to the rapid development of technology, it is also important to have a record of which designs have what affordances. This will help significantly in the future when considering design options for the progressed technology. Knowing what aspects have worked in the past and what has either never worked or been phased out (eg. old rotary phones), will be a giant step in the right direction when designing new state of the art technologies.

Literature Reviews

Current State of the Art

As technology evolves so rapidly it’s important for the health of our study to keep up to date with the current state of the art. Thorough research showed us that the topic of affordances and human computer interaction in relation to AR and VR, are an important and popular discussion. With that being said, we found that the question we were specifically trying to answer, “Why do people behave differently when using AR compared to VR?”, was relatively unexplored territory, as we were unable to find papers which directly matched our subject matter.

This was highlighted in Dalgarno et al’s seminal paper, in which they identify the current literature surrounding 3D learning environments (which encompass both AR and VR). He claims “Much of what has been published about the educational uses of 3-D technologies is largely ‘show-and-tell’, presenting only anecdotal evidence or personal impressions that cannot be usefully generalised beyond the local context.” It is clear from this statement that there is a clear lack of research in the use of these 3D environments and their empirical nature. They advocate for a newly formed research focus on empirical studies relating to the HCI of these environments.

Although, to say that there is no research pertaining to our area would be misleading. Khademi et al. explores the use of Augmented Reality Headsets compared to Non-Immersive Virtual Reality tasks. The results show superior performance in AR, although very limited discussions were made pertaining to the reasoning behind this as the research was quantitative and did not specifically explore the HCI of both environments. [2]

For our individual literature reviews we chose to explore some periphery topics surrounding our research question, which we hoped would give us more context for our pilot study.

[1] "What are the learning affordances of 3-D virtual environments ...." 20 Dec. 2009, https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-8535.2009.01038.x. Accessed 2 Jun. 2020.
[2] "Comparing" pick and place" task in spatial Augmented Reality ...." https://www.ncbi.nlm.nih.gov/pubmed/24110762. Accessed 2 Jun. 2020.

Literature Review 1 - Authored by Razi

Reference: (Brown E, Cairns P, 2004) https://dl.acm.org/doi/pdf/10.1145/985921.986048
There have been other attempts to conduct qualitative research on other computer systems. Brown et al. experimented using a Grounded Theory technique to theorise about video game immersion.

They conducted a small-scale study involving interviewing seven gamers after playing their favourite game for 30 minutes. This was done to prime the interviewees allowing them to better reference their answers for the interview. It is important to note, that the observer ensured that demand characteristics in their study was minimised by carefully wording interviews.

These interviews were then processed using Grounded Theory Techniques. This qualitative technique is effective at drawing conclusions from narrative and observation based studies with few participants. They conducted open coding to identify concepts and categories and subsequently performed axial coding, to connect these concepts and categories.

Overall, they identified that immersion was not a single concept. Instead, they had found that immersion could be further divided into levels including engagement, engrossment and total immersion.

- Engagement involves a baseline investment of time, effort and attention
- Engrossment connects with the gamer's emotion
- Total immersion is complete presence in a virtual world to the point where they are 'detached' from reality. These levels of engagement are interesting, and can be highly relevant to the research question at hand.

They also found that the idea of immersion was not a static experience, and is not a sufficient condition for enjoyment. Another key claim is that the existence of usability and control problems can hinder the effect of immersion and engagement. This claim highlights the importance of good interaction techniques, and a sophisticated understanding of HCI associated with these interaction techniques.

From this study, we can deduce the feasibility of using a grounded theory approach for HCI research. The research techniques outlined in this paper and their approach of a small sampled pilot study would become highly relevant for our project. Using data coding techniques such as open coding and axial coding, Brown et al produced seminal work pertaining to HCI and Immersion. Another key takeaway is that immersion is subjective and dependent on the interaction technique used. Thus, to explore the immersive affordances of a particular interface, careful consideration needs to be made in regards to the interaction technique of the interface.

Literature Review 2 - Authored by Melissa

Reference: (Gjøsæter T, 2014) Affordances in Mobile Augmented Reality Applications

Augmented Reality (AR) has many uses and is becoming widely popularised for a variety of uses. It is becoming more accessible with more affordable headsets and AR support in readily available devices, namely mobile phones.

In a paper written by Gjøsæter, the affordances of mobile applications using augmented reality is explored. The paper covers the usages of mobile augmented reality, as well as it's affordances. They conducted their study using an iOS platform named ARad. Their justification of the usage of this specific platform is that it "incorporates Azuma's three characterizing properties" referring to Azuma's three defining properties of AR. While this platform matches the properties, it'd have more impact to have possibly a second platform to test with for fairness and more data points.

The study consists of individuals performing tasks and overall using the mobile augmented reality (MAR) platform how they would intuitively. This helps gain an understanding of the affordances and the common patterns of use the users intuitively tend towards without instruction.

The paper summarises the types of affordances in AR applications, listing:

- Learning affordances: affordances linked with learning to use the application
- Maintenance affordances: affordances linked with taking care of the application
- Aggregation affordances: affordances linked with the intertwining of other artefacts
- Remediation affordances: affordances linked with the actual content of the application

These affordances are very high level and for a deeper study it would be beneficial to see a more low level approach in defining affordances for more specificity and deeper understanding of exactly what the affordances are.

The paper goes into depth outlining the types of content in the ARad platform, and what is expected and how they collect their data. For example, excerpted from the paper, "users are instructed to verbalize their actions and thoughts throughout the evaluation", describing the method of gathering the data of the thought process of the participant. The paper outlines that while this is an informal technique, it allows the participant to have an uninterrupted observation stream and allows for less skewed results as the participant takes the lead as opposed to other approaches like heuristic evaluation and cognitive walkthrough. This is a great method for affordance-type studies due to the fact that affordances are based on intuitive actions and behaviours in relation to objects, and to properly determine such affordances it's important to observe the natural behaviour of a participant without interjecting and instructing too much.

Overall, this paper outlines a very sound study relating to the affordances of MAR and more specifically the ARad platform. It very closely relates to the study we are conducting with the affordances of these extended realities, and more specifically the differences in affordance for both AR and VR.

Literature Review 3 - Authored by Harrison

Reference: Pasch, Bianchi-Berthouze, van Dijk and Nijholt, 2009 (link)

“Immersion in Movement Based Interaction”

Communication and interaction in the real world are both heavily tied to the way we use our bodies. This paper says that a richer interactive experience can be achieved by taking advantage of this fact by using physical modes of interaction in virtual experiences. Supposedly skipping the abstractions employed typically by a mouse and keyboard allows people to synthesise the actions they want to make better -- since they just do what they want to do, and don’t have to think about which sequence of button clicks allows them to do the equivalent.

As well as this theory it proposes a framework for judging different levels of immersion in interactive experiences, the requirements for them to occur, features of an experience which may cause them. The lowest level of immersion is “engagement”, which occurs when the user feels that the actions they were attempting to invoke were correctly conveyed through the inputs they made. The next level of engagement is engrossment, which occurs when someone becomes emotionally invested in an experience. The final level of immersion is “total immersion”, this is when there are moments in which the participant in the experience forgets that they are in an experience and it becomes their reality.

Each of these levels can be reached by a combination of factors which increase immersion.

1. Natural controls: when the controls for an experience line up with what a user is expecting
2. Mimicry of movement: when the avatar in the experience mimics the movements of the user
3. Proprioceptive feedback: when the environment responds correctly to the actions of an avatar
4. Physical challenge: when the user becomes competitive with some aspect of the experience

In order to reach these conclusions the researchers conducted a qualitative study featuring Wii Fit, one of the earliest examples of designers using physical movement as a method of control in a game. Each participant was put into a sequence of Wii Fit minigames, each one providing a simplified virtual experience of a different sport (eg. tennis, golf, bowling).

The study found that participants generally felt immersed as a result of the physical based interaction, and in particular felt very in control of their in-game characters. However, participants that had extensive experience with sports in which they were playing the simplified versions complained that they found it jarring as they didn't have the same level of control as in real life.

It's clear from this that some level of middleground needs to be found to make sure that those who remember the affordances of the real version of these physical activities can apply them without becoming frustrated in the simplified virtual versions. I also feel that the paper was a bit biased towards presenting the case for physical movement based interaction, and didn't weigh the merits (say perhaps, in accessibility) of having alternate methods of input.

Aim of Experiment

As there could be numerous affordances related to many areas of AR and VR, our literature review pointed that one promising research area is in the mobility and immersion affordances. Thus, the aim of our experiment is to find out the difference in immersive affordances between AR and VR. Specifically, we are hypothesising the following and will design an experiment to prove it's truth;

Users in AR environments would be more likely to stand up and be mobile compared to when in a VR environment.

Approach

A large scale study with a significant number of participants involving quantitative methods was not feasible given the covid-19 regulations at the time of this study. Coupled with our short turnover time required for this experiment, we decided to apply a qualitative grounded theory approach to answer our research question. Without a concrete explanation of the differences between the affordances of AR and VR, our approach was to allow users to experience the two environments and, using Grounded Theory, observe their differences behaviour and theorise these differences from our observations. The core category we would investigate is affordances in AR and VR, specifically affordances related to mobility and immersion.

Our plan was as follows:

1. Develop a User Task and associated Prototype for both AR and VR that allows us to evaluate the affordances
2. Gather some participants to use our AR and VR Prototypes
3. Observe their behavioural differences between the two
4. Use data coding to uncover concepts and categories pertaining to our core theory.

User Tasks

To evaluate the affordances effectively, we developed tasks that would allow these affordances to arise naturally out of the participants. As we are especially interested in movement and immersion based affordances and its differences between the AR and VR environments, we devised a task involving moving scattered virtual objects around the user. Theoretically the user would be able to complete the task completely stationary (with far interaction techniques) or with mobile movements (walking around the room and using near interaction techniques). We gave them minimal instructions to see what they would naturally prefer in each environment. We ensured that external variables such as our environment, tasks, and interaction technique were controlled. The User Study Script can be found on Appendix 2.

XR Prototype Development

To conduct our user study, we developed an XR Prototype that could be ported for both the Oculus Quest and HoloLens 2 that encapsulates the user tasks that needed to be performed.

Hardware

For our AR prototype, we targeted our build for the [HoloLens 2](), whereas for our VR prototype we targeted our build for the [Oculus Quest]().
The reasoning behind this was that it was essential to control the interaction techniques and interface for both environments. As our AR headset that we would like to conduct an experiment with, the HoloLens 2, fundamentally operated with the use of Hand Tracking, we required that our VR environment also supported hand tracking. The Oculus Quest is one of the few VR Headsets supporting this interaction technique, so the choice to use this was obvious.

Software

We built our prototype upon the framework provided by Microsoft Mixed Reality Toolkit (MRTK).
We did this to ensure that we controlled the tasks for and interaction techniques for both environments. MRTK contains pre-built assets and interfaces for XR environments. It is especially powerful in creating easy to use virtual objects that can be manipulated by hand. Using this framework for both environments ensures that the task completion can theoretically be done in a similar manner to both environments.

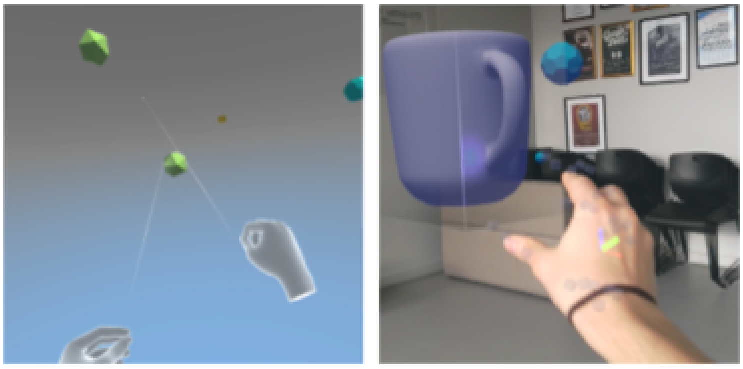

Fig 1. Screenshots of our XR Prototype in use on both the Oculus Quest (left) and HoloLens 2 (right).

Code of the prototype can be found here:
Septian Razi Github: XR Affordances Experiment

Pilot Study

We gathered 5 participants and had each one sign a consent form prior to the commencement of the study (see Appendix 1). Once signed, we had each participant answer some entry questions pertaining to their demographic and experience with the technology. Following this, we had each one complete the given tasks in both the AR environment and then subsequently the VR environment. The tasks in each environment also involved a small tutorial on how to interact with the objects. Once the task was complete or the observer deemed enough data was collected, we ceased the action tasks and had the participants answer some exit questions before de-briefing.

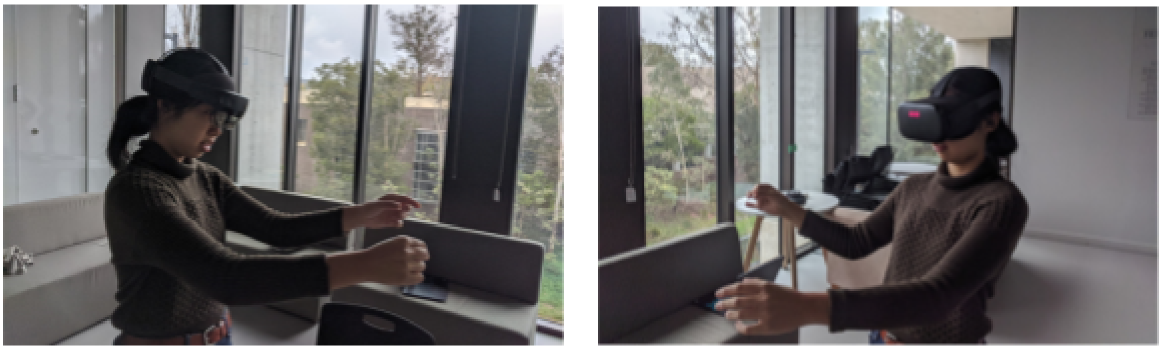

Fig 2. Screenshots of our XR Prototype in use on both the Oculus Quest (left) and HoloLens 2 (right).

The experiment observer was present in the room with them to guide them if they needed help with the program, but otherwise we had given very minimal instructions to the participants. The entry and exit question answers were also transcribed.

Data Coding

After gathering our data and writing down our observations on our document, we applied open coding techniques to find reemerging themes and concepts. Three of these reemerging themes include Mobility of participants, Interaction Techniques with Virtual Objects, and pain points relating to the ease of use of the environments.

After evaluating the open codes, we identify relationships between these codes at a per participant level and at an per environment level. We used Axial Coding to do such that, some of which we have outlined below

Open Codes	**Axial Codes**
Mobility, Interaction Techniques	Certain Movement patterns can be afforded due to the Interaction Technique. We found that if participants were in awe at the interaction technique (scaling, rotating around objects instead of just moving them to the bin) they tended to remain stationary.
Mobility, Difficulty with Program,	Certain Movement patterns can be afforded due to the

AR	difficulty of an alternative For example: Far Interaction while seated on AR not working -> Resorts to moving around and using Near Interaction
Computer Literacy, Previous XR Experience, Mobility	Certain movement patterns can be afforded by the participants ability and confidence in the use of the technology. We found that a high computer literacy correlates to a seated position.

Results

Our results indicate that there may be some level of difference between the affordance of AR and VR, although not to the extent we had initially hypothesised. From the pilot study, we found that 2 of the 5 participants stayed seated throughout the activity, and three stood up and moved around. Of those that did stand up, they were visibly more mobile than when in VR.

Another interesting insight we found was that only one participant verbally recognised that they found Near Interaction Techniques as an easier substitute whatsoever compared to Far Interaction Techniques.

Furthermore, we did identify that computer literacy and experience with VR may actually affect the affordances perceived by participants. Those with a high level of computer literacy chose to remain seated during our experiment.

Outcomes

As we conducted a pilot study and not a full experiment, we are unable to make any sound conclusions from our results due to the small sample size of participants. We were, however, able to test the quality of our experiment and also find other hypotheses to test with our experiment.

Overall, our pilot study ran very smoothly which indicates a few things:

1. Our instructions are easy to understand by participants who have never heard them before
2. The activity isn't too difficult for people of various computer literacy levels
3. The exit questions the participants were asked were useful in finding out the participants thoughts on the exercise they just took part in
4. Doing the AR activity first may potentially have an impact on results, and this should be taken into account or randomised for fairness
5. Long sleeved clothing over hands can affect the hand tracking for both devices, which should be noted before the activity starts

These outcomes of the pilot study are very useful for the future of this experiment as it makes it much clearer where the strengths and weaknesses lie in our activity.

While the main goal of this pilot study was to determine the affordances and any correlations associated with the usage patterns of AR and VR, as mentioned above we found some other possible relationships which determined how each participant behaved during the activity. For example, there was a correlation between the five participants included in the pilot study and the level of computer literacy. The participants who remained seated and less mobile overall had higher computer literacy levels. As this study only included five people, this hypothesis will have to be tested further in order to get a better understanding of any possible correlation between these two attributes. From the information we have gained through this study, it seems that participants who have used AR or VR technologies before were definitely more confident in the activity and therefore were more comfortable staying seated.

The outcomes of this study did not really abide by initial hypotheses. For example, the participants who were more mobile, were mobile for both the AR and VR activities, contrasting to those who stayed seated for both activities. It was expected that participants would stay seated for VR but move around for AR. Obviously, this wasn't the case however it was observed that the participants who did stand up were more agile for the AR activity than the VR activity, which somewhat follows our hypothesis.

Overall, the pilot study results indicated there could be some level of difference in affordances for both VR and AR. This study is not conclusive due to the sample size however it is a very solid foundation to build off of for future research in the area.

Next steps

The pilot study had a very small sample size, and as such it's difficult to draw concrete conclusions from our observations. In the future it would be prudent to revisit our experiment with a larger amount of participants to see if the findings are replicated or not.

The smaller sample size meant that our conclusions from our pilot study were far from statistically credible. This is due to the amount of context and prior findings required for a sound experiment to be conducted in order to directly identify affordances in AR and VR and also the differences between the two technologies. Although, it does offer insights surrounding our original research question and other considerations. In the next steps, it would be important to continue to rework the experiment to bring it closer to a more concrete answer to the proposed question in order to complete this study.

There are definitely avenues from our research to follow, and that would benefit from being analysed further. Such avenues are:

- Look into how tech literacy impacted the way in which participants approached our AR/VR experience. It's easy to imagine how someone more confident with technology would be more brazen in their experimentation with these new devices.

- Track biometric or quantitative data for participants like heart rate, movement heat maps to see how each of these changes in the different environments.

There are many steps which can be taken to bring this study further and this information will continue to be useful in answering the overarching question of the differences in affordances between AR and VR.

Reflection

Overall, the pilot study was a success, however if it was to be repeated we may also change up our methodology a bit. Some suggestions include:

- While the tutorial definitely helped make sure everyone was on the same level of understanding, we think having them do a little more unscripted practise may have done more to bring everyone up to the same level of skill
- We also may have biased some of our results by introducing VR first -- so we would need to control for that too. We could even go further and test if this does make a difference by having two groups.
- We would have also liked to improve the quality of our data by asking more relevant entry and exit questions. The data coding section was significantly harder due to our lack of topical and relevant questions. For example, if they have normal eyesight, if they have experience with video games and other questions relevant to immersion.

What our pilot study did manage to accomplish well was its opening up of numerous different research pathways for us to explore that we did not know existed beforehand, from connection between computer literacy and mobility to more advanced and quantitative methods of tracking mobility (eg: Heat Maps). If we had more time and were able to conduct proper user studies we would have been eager to explore these findings in more depth. We also are proud of our accomplishment of this research project under a global pandemic, adapting well to the necessities of research by pivoting to a qualitative method.

Team Distribution of Work

Task	Assignee
Background	Melissa
Rationale	Harrison
State of the Art	Razi
Literature Review 1	Harrison
Literature Review 2	Razi
Literature Review 3	Melissa
Aims	Harrison
Approach	Razi & Harrison
Outcomes	Melissa
Next Steps	Melissa
Reflection	Harrison

Justification

As a diverse team with different expertise and experience, our team carefully considered the optimal distribution of work to ensure both fairness and quality of our assignment.

Razi, having extensive experience with Augmented and Virtual Reality, was assigned mainly with the task of conducting our experiment. He also possessed the Hardware necessary for the experiment, namely the Oculus Quest and the HoloLens 2. Thus, Razi spearheaded the development of the XR prototype and the conducting of the experiment in person.

Harrison, whose expertise lies in HCI and with extensive experience in HCI projects, was quite familiar with the intricacies of a study of this nature. Therefore, he was best suited for spearheading the aims of our experiment that was relevant to our research question and designing a user study to answer it.

Melissa has a passion for emerging technologies and the innovation of the HCI component of them. Melissa is highly skilled at analysis, and was best suited to conduct data coding on the notes and observations from the experiment. Her analytical skills allowed her to identify connections between our open data codes into tangible categories and theories.

As a team, we all ensured to assist one another to get the best outcome possible. This helped us in utilising each other's writing and analysis strengths for related parts.

Appendix 1 - Consent Form

Written Consent for Participants of

COMP4450 Assignment 4 Group 35 User Testing

Evaluation of Affordances in VR and AR

I have read and understood the Information Sheet you have given me about the research project, and I have listed any questions and concerns about the project here (Optional)

And they were addressed to my satisfaction.

I agree to participate in the project. YES☐ NO☐

I agree to be identified in the following way within research outputs:

Full name	YES ☐	NO☐
Pseudonym	YES ☐	NO☐
No attribution	YES ☐	NO☐

Signature: ______________________________

Name: _________________________ Date: _____ / _____ / __________

Appendix 2 - User Study Plan

Objectives of Testing

- Understand the affordances that people naturally use to interact with VR/AR artefacts
- Understanding concrete behavioural differences between AR and VR

Entry Questions

1. Male/Female/Other?
2. Age?
3. Occupation?
4. Qualifications and Length of Experience in Field?
5. Previous Experience with VR/AR?

Notes: Ensure before the action script commences;

- Sessions are being recorded on the XR hardware
- XR Prototype has been restarted
- Experiment observer is actively observing and noting behaviours of participants

Action Script

- **Tutorial of AR Prototype**
    - Example of a Far Interaction Technique
    - Example of a Near Interaction Technique
    - Tasked to place virtual object in a virtual bin

- **Actions to Complete in AR**
    - Instruct participants to place all virtual objects in the bin
        - Give them no additional instruction to allow natural affordances to occur and prevent demand characteristics[3]
    - Identify a Virtual object
    - Interact with the object and place it in the virtual bin
    - Repeat until a sufficient number of objects have been placed in the virtual bin

- **Tutorial of VR Prototype**
    - Example of a Far Interaction Technique
    - Example of a Near Interaction Technique
    - Tasked to place virtual object in a virtual bin

- **Actions to Complete in VR**
    - Instruct participants to place all virtual objects in the bin

[3] "The Effects of Demand Characteristics on Research ... - NCBI." 19 Jun. 2012, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3378517/. Accessed 2 Jun. 2020.

        - Give them no additional instruction to allow natural affordances to occur and prevent demand characteristics[4]
    - Identify a Virtual object
    - Interact with the object and place it in the virtual bin
    - Repeat until a sufficient number of objects have been placed in the virtual bin

Exit Questions

Questions on Experience

1. How was the experience of finding Virtual Objects?
2. How was the experience of interacting with Virtual Objects?
3. How intuitive were the interaction techniques in the experiment? Was one environment more intuitive than the other
4. What felt natural in AR? Was it different to VR?

[4] "The Effects of Demand Characteristics on Research ... - NCBI." 19 Jun. 2012, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3378517/. Accessed 2 Jun. 2020.

Appendix 3 - Participant Information Sheet

Researchers:
We are a project group of COMP4450 students at ANU (Australian National University) who are investigating the differences between Augmented Reality Head Mounted Display use and Virtual Reality Head Mounted Display use.

We are:

Septian Razi - Contact: septian.razi@anu.edu.au
Melissa Turner - Contact: melissa.turner@anu.edu.au
Harrison Shoebridge - Contact: harrison.shoebridge@anu.edu.au

Project Title: Evaluation of Affordances in VR and AR

General Outline of the Project:

- **Description and Methodology:**
  We are performing a user study on AR and VR on a prototype to assess and observe several behaviours when interacting in the two different environments. We will ask you to perform certain actions in our prototype and observe your responses to these actions. We will also ask several questions before and after the evaluation to gain further insight into your behaviour.

- **Participants:**
  Five adult, voluntary participants chosen to perform the user testing. We have abstained from choosing participants who have knowledge in regards to HCI, XR and affordances.

Participant Involvement:

· **Voluntary Participation & Withdrawal:**
  - o The participation for this study is **voluntary** and you may leave at any time, from the start of the study until the data is published, without providing a reason.
  - o You may also withdraw completely, at any time from the start of the study until a day before the data is submitted for marking (final withdrawal time: 2nd June, 12:00pm), in which case your information which you have provided, as well as your results, will not be used in the study and any information already within our holding will be destroyed in a confidential manner.
  - o There will be **no** negative consequences if you choose to leave or withdraw.
  - o You are able to, at any time, refuse to answer a question or refuse to follow an instruction.
  - o You may ask the reason for any question or instruction at any time.

- **<u>What does participation in the research entail?</u>**

  In this study you will be asked to follow instructions given by a person or the prototype, and asked to answer follow up questions regarding the prototype. During the process of the study, your actions will be observed and noted by one observer and used only for study purposes. Your behaviour through the head mounted displays would also be recorded. Your data will be viewed by us (the researchers) and possibly the assignment markers of the COMP4450 course. Data from the evaluation will be aggregated and identifying data such as name, gender, and age will not be included in the published version **unless you have agreed** to have it included on the consent form – this does **not** mean that it **WILL** be included, only that it may.

- **<u>Location and Duration:</u>**

  The research will take place on the ANU campus at the TV Room of Fenner Hall, you will be required to interact with our AR prototype only once and our VR prototype once. The entire process will take between 10 and 20 minutes.

- **<u>Risks:</u>**

  There may be some discomfort and nausea associated with VR or AR Head mounted displays. Due to the nature of the shared equipment, there is also a risk of contamination. We sanitise our equipment between use regularly to ensure this risk is minimised.

Appendix 4 - Results and Notes

Josh (1)

a. **Entry Questions**
   i. Male/Female/Other? **Male**
   ii. Age? **19**
   iii. Occupation? **Chemistry/Music Student**
   iv. Qualifications and Length of Experience in Field? **Student for 1 Year**
   v. Previous Experience with VR/AR? **None**

b. **Action Script Observations**
   i. VR
      1. *Remained Seated experience*
      2. *Mostly used Far Interactions*
      3. *Hand Tracking Seems much easier in this situation*
   ii. AR
      1. *Mostly Seated Experience*
      2. *"Less Intuitive than the VR experience"*
      3. *Had difficulties with the latency and reaction of the HoloLens2*
      4. *Completion time was longer*

c. **Exit Questions**
   i. How was the experience of finding Virtual Objects?
      Was really cool, and seemed pretty intuitive once you got the hang of it

   ii. How was the experience of interacting with Virtual Objects?
      The hand rays thing was helpful, and bit more accurate in the VR headset. It'd be interested to see how far away the objects can be to touch the hand rays

   iii. How intuitive were the interaction techniques in the experiment? Was one environment more intuitive than the other
      The VR seemed much more responsive but overall it was quite difficult.

   iv. What felt natural in AR? Was it different to VR?
      I think they generally felt similar, it was actually a bit harder to see the objects in the AR headset so I had to squint a bit more

Yona (2)

a. **Entry Questions**
   i. Male/Female/Other? **Female**
   ii. Age? **20**
   iii. Occupation? **PPE/Music Student**
   iv. Qualifications and Length of Experience in Field? **Student for 3 Year**
   v. Previous Experience with VR/AR? **None**

b. **Action Script Observations**
   i. VR
      1. *Stood up and walked around*
      2. *"I don't know how others did it sitting down"*
      3. *Mostly used near interactions*
      4. *Used far interactions when outside the border*
      5. *Liked resizing objects*
   ii. AR
      1. *Actually walked confidently towards the items*
      2. *Participant mentioned the limited field of view*

c. **Exit Questions**
   i. How was the experience of finding Virtual Objects?
   That was soo cool! They were pretty easy to spot around me

   ii. How was the experience of interacting with Virtual Objects?
   It's alright, sometimes the rays didn't work as well so I ended up just picking them up.

   iii. How intuitive were the interaction techniques in the experiment? Was one environment more intuitive than the other
   I think both were pretty intuitive, the AR was a bit slow though.

   iv. What felt natural in AR? Was it different to VR?
   I guess in AR, seeing as I could see the objects around me I was a bit more comfortable in it.

Locklyn (3)

a. **Entry Questions**
   i. Male/Female/Other? **Male**
   ii. Age? **20**
   iii. Occupation? **Cyber Security Student**
   iv. Qualifications and Length of Experience in Field? **Student for 3 Year**
   v. Previous Experience with VR/AR? **Minimal**

b. **Action Script Observations**
   i. VR
      1. *Remained Seated for the entirety of the program*
      2. *Participant seemed quite adept at the program*
   ii. AR
      1. *Remained seated for the entirety of the program*
      2. *Participant remained quite adept at the program, even with the added limited reaction of Hololens 2*
      3. *Participant mentioned the limited field of view*
   iii. Observation
      1. *Adeptness with Computers may contribute to confidence*

c. **Exit Questions**
   i. How was the experience of finding Virtual Objects?
   Yeah nah it was pretty sick, the ones behind me were a surprise - took forever for me to find them

   ii. How was the experience of interacting with Virtual Objects?
   Yeah was alright, I think the AR goggles need to be a bit better in terms of usability, but grabbing objects was quite alright.

   iii. How intuitive were the interaction techniques in the experiment? Was one environment more intuitive than the other
   I think the VR seemed to respond to my hands better and made it easier.

   iv. What felt natural in AR? Was it different to VR?
   I dunno know really, it seemed like for both it was similar, except of course the latency with the AR.

Jake (4)

a. **Entry Questions**
   i. Male/Female/Other? **Male**
   ii. Age? **23**
   iii. Occupation? **Mathematics Student**
   iv. Qualifications and Length of Experience in Field? **Student for 5 Year**
   v. Previous Experience with VR/AR? **None**

b. **Action Script Observations**
   i. VR
      1. *Remained Seated*
      2. *Seemed quite impressed with Scaling capabilities of Virtual Objects*
      3. *Stood up when finding any nodes he missed, but then sat back down*
         a. *Stood up when attempting to grab a node above him*
         b. *Even stood on a chair!*
   ii. AR
      1. *Remained Seated in the entirety of the program*
      2. *Mentioned the narrow field of view*
      3. *Mentioned Hitboxes of objects*
      4. *Also stood up when finding nodes he missed.*

c. **Exit Questions**
   i. How was the experience of finding Virtual Objects?
   Yeah was alright, it was quite easy for me to find the objects around, if i looked around enough

   ii. How was the experience of interacting with Virtual Objects?
   So cool. The whole dragging and rotation and scaling stuff, that's super sick. I wish i could just shoot rays out of my hand and grab stuff like that.

   iii. How intuitive were the interaction techniques in the experiment? Was one environment more intuitive than the other
   Hmmm I dunno about intuitive. They both seemed to be pretty intuitive, but yeah the AR environment hand tracking seems a bit slow. I feel like once you use it often you'd be a pro at this pretty quickly.

   iv. What felt natural in AR? Was it different to VR?
   Natural? That's a hard question really. I dunno, grabbing objects between the two seemed similar enough.

Trish (5)

a. **Entry Questions**
   i. Male/Female/Other? **Female**
   ii. Age? **20**
   iii. Occupation? **Medical Student**
   iv. Qualifications and Length of Experience in Field? **Student for 2 Years**
   v. Previous Experience with VR/AR? **None**

b. **Action Script Observations**
   i. VR
      1. *Rolled up sleeves interfere with the hand recognition*
      2. *Incessantly laid out hands in front of her in the wrong position (supinated hand)*
      3. *Was less mobile and weary of tripping on real life objects unseen due to the virtual environment*
   ii. AR
      1. *Actually ran to objects (and not walked) much more confidently*
      2. *Was much more mobile*
         a. *Even willing to stand up on furniture surrounding*
      3. *Still mistakenly used a supinated hand from time to time*
   iii. Observations
      1. *Participant took an extremely long time to finish task and did not complete both tasks fully in the end.*

c. **Exit Questions**
   i. How was the experience of finding Virtual Objects?
   Was hard, I'm sorry I couldn't finish the task. There was just so many objects!

   ii. How was the experience of interacting with Virtual Objects?
   Oh my god - difficult? It kept on not working with my hands.

   iii. How intuitive were the interaction techniques in the experiment? Was one environment more intuitive than the other
   Lol both were pretty hard. Like I don't know if that helps but it seemed like the program just doesn't like me.

   iv. What felt natural in AR? Was it different to VR?
   Natural? I think I naturally suck at both. Haha just kidding. They seemed pretty similar in that I was a bit scared of bumping into stuff in the VR.

Overall observational conclusions:

- Those that chose to remain seated did so for both platforms, and as well as standing
    - Three Participants remained seated
    - Two participants stood up
- But, of those that stood up, were much more visibly mobile during the AR
    - This may be due to increase spatial awareness in AR allowing fro more confident movements to be made
- There seems to be a correlation between computer literacy and the ability to do experiments sitting down?
    - Perhaps better computer literacy meant that people were more confident when sitting down during these observations
- Participants did not find near interaction techniques easier than the Far Interaction Techniques except for one participant claiming "*sometimes the rays didnt work as well so I ended up just picking them up.*"
- Participants all were quite enthusiastic working with this new technology.

Coding Keys and Categories

- Related to difficulty of use (Hand Tracking Problems) in AR
- Related to mobility of participants
- Related to Interaction Techniques with Virtual objects
- Related to Computer Literacy and Previous Experience