User Experience Survey of Augmented Reality Mobile Applications and Their Effects on Mobile Devices

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Abstract

Augmented Reality mobile applications are becoming more and more frequently developed. Since Apple's ARKit was released in 2017, there have been more than 2,000 augmented reality apps added to the App Store. Although there have been more augmented reality apps created, there has been little research done on the user experience. Augmented reality is at a point where it's been well developed and needs to start looking at users to make it usable, useful, and immersive. The purpose of my research is to study different features and qualities of augmented reality apps which effect the user experience.

In order to do this, I do a competitive survey between 15 different apps. I do both a qualitative and quantitative survey of the apps. For the qualitative testing, I create a survey to be sent around to various people of different ages and background. The survey covers different qualities and features as well as how realistic the augmented reality objects appear. Then for the quantitative testing, I test the effects of augmented reality apps on a mobile device's battery life, data usage, and loading time. I also do a personal analysis of some additional features I noticed while playing with each app.

This research helps show where developers can focus on for improvement in future augmented reality apps. It also shows where further testing would be helpful and is needed in order to help augmented reality apps progress. Users can make or break a technology depending on whether or not they actually want to use it. The research in this paper can help give guidance to future user research. It also can help developers of augmented reality apps in knowing how they can make their apps better when it comes to the user experience.

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User Experience Survey of Augmented Reality Mobile Applications and Their Effects on Mobile Devices

Augmented reality and UX Design have a few commonalities. First, both started around the same time. In 1948, Toyota began valuing employees input as much as the engineers and producers. The employees brought attention to the actual interactions users would have with their products. Due to this, Toyota had great success and brought attention to a new technological field focusing on user's experiences (Tariq, 2015). Then, in the 1960's, augmented reality had its start when Sutherland used a see-through HMD to show 3D graphics (Azuma, et al., 2001).

As the years went on, augmented reality began to develop. Then, just as augmented reality and other advanced technologies began to develop, the need for UX became more apparent. They both got their terms coined in the 1990's. Augmented Reality was coined by Thomas Caudell and David Mizell in 1992 (Azuma, et al., 2001). They were asked to create a cheaper and more efficient way of guiding workers on the work floor. They came up with a way to show instructions using a head-mounted gadget. The eye-ware would then project the instructions which could then be updated quickly with new instructions when needed ("AR at Boeing (1990)").

Then UX Design was coined by Don Norman, who was the Vice President of Advanced Technology Group at Apple in 1990. He said, "I invented the term because I thought human interaction and usability were too narrow. I wanted to cover all aspects of the person's experience with the system including industrial design, graphics, the interface, the physical interaction, and the manual" ("UX Design Defined"). Since then, UX Design has become an up and coming tech field focused on making sure new technology is human centered. UX Designers allow humans to take control of their technology and use it for their advantage.

UX Design is necessary to help augmented reality reach its full potential. With new technology comes new problems. This is why it's important to do UX testing on augmented reality. Augmented reality has been studied for around 20 years, but little focus has been put on studying the actual user experience.

My purpose with my research is to look into the actual user experience of augmented reality applications on the iPhone. With the new ARKit released by Apple it is easier for creators to develop augmented reality apps. There's new problems that arise from augmented reality apps which may not have been a problem for none augmented reality apps. These apps have a lot of potential, but they won't be realized unless they give a great user experience.

Right now, some problems with augmented reality applications include their possible effects on battery life, speed, and storage space on the iPhone. These aspects are just as much a part of the user experience as much as how well a user can use the app. No one wants to use an app which will drain their battery life in twenty minutes or will take up all the space on their iPhone. Other problems effecting the user experience include the quality, usability, and usefulness of the applications. I test both quantitative and qualitative aspects of the user experience in order to help future developers and designers in creating successful augmented reality applications.

Historiography

As mentioned before, augmented reality has only been studied for 20 years. There's still much to learn about it especially when it comes to the user experience. From 1998 to 2004, there's been a total of 1,104 studies published on augmented reality. Out of all those studies, only 21 of them were focused on user-based experiments (Swan II & Gabbard, 2005). This means only 2% of all research has been focused on the actual users. This is crazy especially

when users in the end will make or break a technology depending on whether or not they want to use it.

Looking at the other user-based research papers none of them focused specifically on augmented reality mobile applications. There was a study done by Markus Salo and Thomas Olsen who did an online survey of augmented reality applications on devices like Layer, Junaio, Google Goggles, and Wikitude. They also only tested experts and who had a lot of previous experience in augmented reality (Olsson & Salo, 2011).

There was another study done by the same researches and looking at the same devices. They researched satisfying and unsatisfying experiences with augmented reality applications, but they were only looking at it from an entertainment aspect. Having entertaining apps are great and help get new technology noticed, but how useful an application is will help a technology have longevity (Olsson & Salo, 2012).

This is why for my research, I wanted to focus just on mobile applications. ARKit has opened up a whole new market for augmented reality applications. There hasn't been any study done on them yet. I also wanted to get real everyday users. I didn't want to just test on users with previous experience with augmented reality or who are in the UX field. I wanted to get all users since augmented reality apps will be used by everyone.

Survey and Test Set up

A reason augmented reality may not have been tested too much on mobile devices is because they have just recently been being more developed for the phone. When Apple released ARKit, there was a great increase in the development of augmented reality applications. There are now over 2,000 augmented reality apps, whether they were created using ARKit or not, in the App Store today. Also, from September to June, there were 13 million downloads of augmented

reality apps created using ARKit (Perez, 2018). Augmented reality is becoming much more available to everyone as it's now accessible through mobile devices. Due to this, and with any phone application, it's important to make sure it gives the user a good experience.

By good experience, I mean the application first needs to be usable. It needs to be intuitive and easy to use. Users need to be able to easily understand how to use features which will allow them to access the full capabilities of the app. Second, the app needs to meet the needs of a user. Sure gimmicky apps have been successful, but more often it's the apps which provide a service to a user which are the most successful. Whether the use is for entertainment, work, or to connect with others, an app which helps a user with an immediate need will be used most often. Lastly, the app needs to be immersive. It seems easy for an augmented reality app to be immersive as virtual objects appear to be a part of the real world, but if there are technical difficulties, it'll ruin the immersive experience.

In order to help future developers create greater user experiences, I decided to do a competitive test of different augmented reality iOS applications. I chose to just focus on iOS due to time constraints. I used the iPhone 8 and majority of the applications chosen were also created using ARKit.

I did both quantitative and qualitative testing. For the quantitative testing, I tested the effects of augmented reality applications to the actual device. I tested how they effected battery life, data usage, and their download speed. Then for qualitative testing, I focused on their usefulness, design, and how realistic the augmented reality elements appear.

There are many different categories of augmented reality apps so in order to do a competitive analysis, I wanted to test apps within similar categories. I selected 3 categories I felt

had the most potential with augmented reality. I chose to test social, shopping, and gaming augmented reality applications.

About the Apps Selected

After choosing the categories, I selected five apps within each category. For selecting apps, I wanted to choose ones which were popular and already well developed. I wanted the apps to have these qualities so they'd all be on more equal playing fields when comparing them to each other.

For the social apps, I selected Snapchat, Instagram, Facebook Messenger, Holo, and GIPHY World. Snapchat, Instagram, and Facebook Messenger all use Augmented reality in their apps to allow someone to distort, change, or add to their own or others face and surroundings. This is referred to as lenses or filters. These apps began using these augmented reality filters or lenses before ARKit was released. They are the only 3 apps which didn't use ARKit to apply augmented reality.

The other two apps, Holo and GIPHY World: AR GIF Stickers, have different uses for augmented reality and were created using ARKit. The purpose of these apps is to take popular gifs, memes, and celebrities, and allow a user to place them into their real world. It's like getting to apply moving stickers all over your surroundings. A user can then share their creations with friends and family.

The next category is shopping apps. I chose IKEA Place, Amazon, Magnolia Market, BMW iVisualizer, and FittingRoom. All these apps let a user see products in their actual size and in their own homes. Using augmented reality in shopping apps changes the at home shopping experience completely. The apps allow you to almost literally try before you buy.

Lastly, for augmented reality gaming apps, I went with Pokémon GO, Alice AR Quest, Lego AR Studio, AR Dragon, and Stack AR. Using augmented reality in gaming apps has made users become more active. A lot of the games require a user to get up and explore their surroundings.

Adding augmented reality to social, shopping and gaming apps have added a new dimension to iPhone applications. They've brought users a new and more immersive experience. They all have different user experiences and for them to continue to develop, these experiences need to be tested. I first began with the qualitative testing.

Qualitative Testing

In order to test the quality, I created a survey for testers to take to assist me in analyzing the quality of these apps. This survey asked general background questions of each participant. These background questions included:

Background Questions

1. Age
2. Area of Study/Career Field
3. Previous experience of AR apps on a scale from 1-10

I asked these background questions because I wanted to make sure the results represented a general audience as past studies have not done this. The survey was posted on social media in order to get a wide variety of testers. It was also sent out in an email to all students in the Media Technology program at FH St. Pölten. Although the students would probably have a background in augmented reality or user experience, it was necessary to send in order to get a higher quantity of responses. In the end, there was a total of 52 responses.

The age for the testers had a range from the youngest being 19 and the oldest being 60. The median age of testers was 27 (see Figure 1). There was a wide range of testers with different careers and areas of study. A lot of responses did come from people in the Media Technology industry like UX Design, Graphic Design, Interaction Design, Audio and Video, Mobile Development, and Computer Science. There were also a lot outside of the Media Technology field like Accounting, Biology, Business, Medical, Political Science, and Psychology.

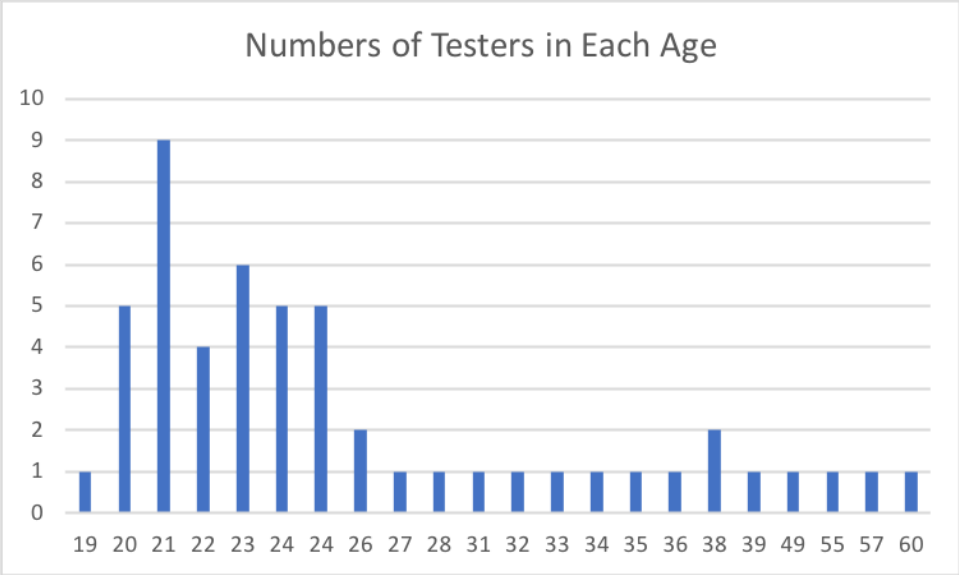

Figure 1. A visual representation of the number of testers in each age.

Everyone also had varying degrees of previous experience with augmented reality apps. The median experience was a 5 which is perfect. I wanted to get testers on both ranges of the spectrum. There were 27 who responded with a 5 or less and 25 who responded with higher than a 5 (see Figure 2).

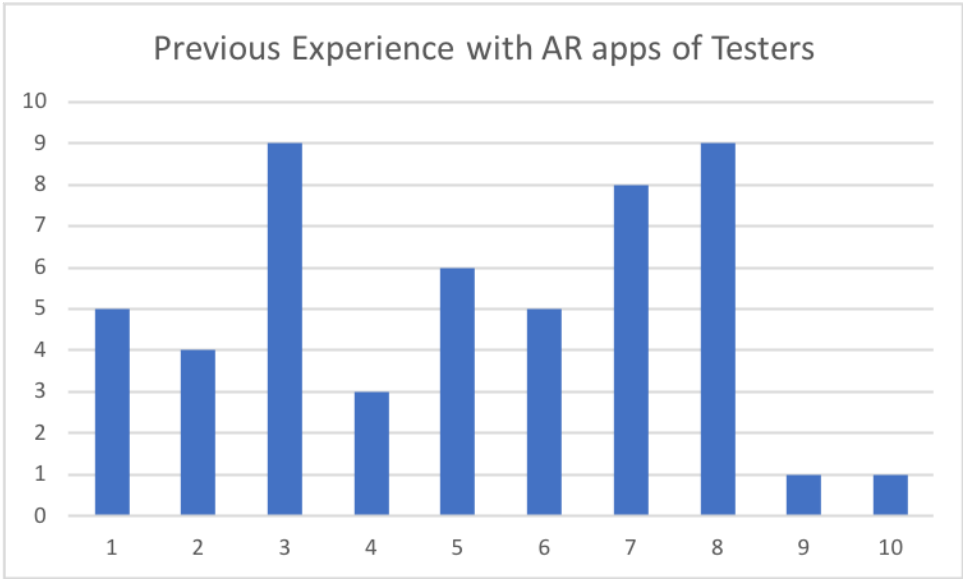

Figure 2. Full results of tester's previous experience with Augmented Reality.

Testers backgrounds were all around varied. There was a wide range of ages, area of studies & careers, and experience with augmented reality. This was the result I was hoping for. I wanted to get a more general audience as this hasn't been done in any augmented reality testing before. It'll also help key in on true issues of augmented reality apps. Sometimes experts can miss the true problem because they have biases, or they are going off of their own opinion.

Another good reason to test general users is developers could spend a lot of time trying to fix one problem when the users were more concerned with a different problem. It's important to check-in with real users because they provide insight into the true problems of applications. They can help save developers time by showing them what problems they actually care about.

Features and Usefulness

In order to find what I wanted to put into the survey, I went through each app and played around in each of them first. I took note of interesting features as well as differences between each. I also took note of features I saw which I wanted to test to see if they'd be useful for a user. In the end, I came up with these survey questions for the features and usefulness:

1. Where are you likely to play AR games on your phone?
2. Many AR games require players to move around and explore, when and where would you be more likely to play these games?
3. What do you think of being able to take photos or screen recordings within an AR app?
4. If a store offered the ability to shop with AR, would you prefer it be a separate feature within the store's current app, have a separate AR app, or be an option that only shows up on elements that can be seen in AR?

Where are you likely to play AR games on your phone? I noticed some of the apps seemed better suited to be played outside and some seemed more fitted for inside. A lot of the gaming apps worked better outside. Alice's AR Quest, Pokémon Go, and AR Dragon all required wide space in order to use them effectively. This is 3 out of the 5 so I focused this question toward the gaming apps. They could answer inside, outside or both.

49% said both while 25.5% said inside and 25.5% said outside (see Figure 3). The reason majority may have said both is it does depend on the apps purpose on whether or not it works better inside or outside. For example, Pokémon GO puts different Pokémon in different locations, so a player has to be outside and walk around in order to find them. The developers wanted to get users to be more active. As I was looking for apps to test, I noticed a few other augmented reality apps which used this same concept.

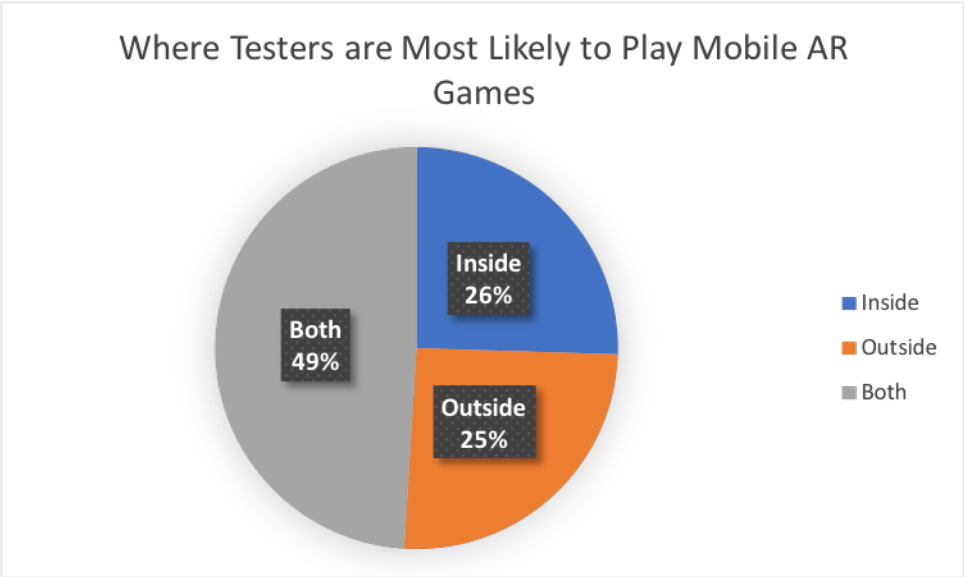

Figure 3. Graph representing where testers would prefer playing AR games.

On the other hand, the game Stack AR requires a player to be more still and focused. A player's purpose is to take flat square bricks and stack them right on top of each other. If a player doesn't get a brick right on top, it makes the next brick smaller making it harder and harder to stack. Running around would actually make this game harder to play. This is why majority said both because it just depends on the concept of the app. Knowing players are willing though to play inside or outside is a good note for developers because now they know there's an audience for both. Now we know this about users, we can delve more into the experience of playing augmented reality apps inside or outside.

Many AR games require players to move around and explore, when and where would you be more likely to play these games? Continuing on with playing games inside or outside, I wanted to get more specific. As I was playing some of these apps myself, I wondered if users might feel silly running around a park with their face buried in their phones. I know I did! The testers could answer inside by myself, inside with others, outside by myself, or outside with others. The testers were also able to check multiple options.

The highest result was 70.6% on testers rather wanting to play augmented reality app games outside with others. On the other hand, the response of playing outside by yourself got the lowest result with 37.3% (see Figure 4). This is important to know because if developers create apps which are meant to be played outside, they should add a collaborative feature to their apps. The answers were about half and half between playing inside by oneself or with others. Users could go either way inside but outside they'd rather play the games with others. Further research could be done on figuring more out on what a user would prefer for an augmented reality app which is meant to be played outside.

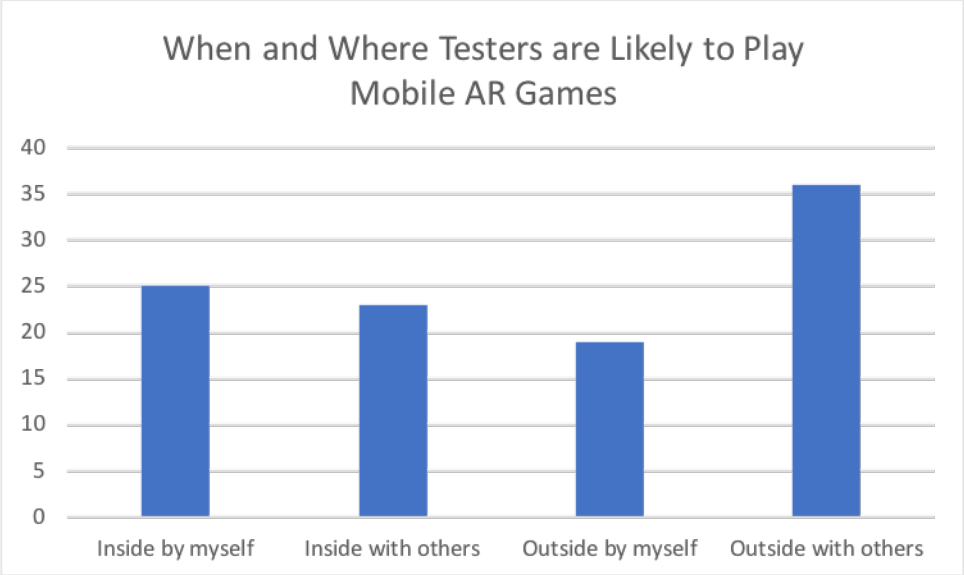

Figure 4. A graph showing when and where testers are likely to play AR games.

What do you think of being able to take photos or screen recordings within an AR app? Next survey question was on a feature I noticed from exploring which was different from non-augmented reality apps. Some apps had a feature where a user could take screen shots or screen recordings within the app. This replaces having to push the home and lock button at the same time to get a screen shot. Testers could answer useful, not useful, useful on certain types of

apps, or not sure. Majority of testers said it would be useful on certain types of apps (see Figure 5). This is similar to the outside vs inside survey question response.

It comes down to the purpose of the app and who your audience is going to be. For example, this type of feature could be more useful on shopping apps. This is because a user can easily take screenshots to remember different products and how they looked. It eliminates a step making for a more fluid process. The feature may be less necessary on gaming apps though. Further testing would need to be done to see which apps this feature would be most appreciated.

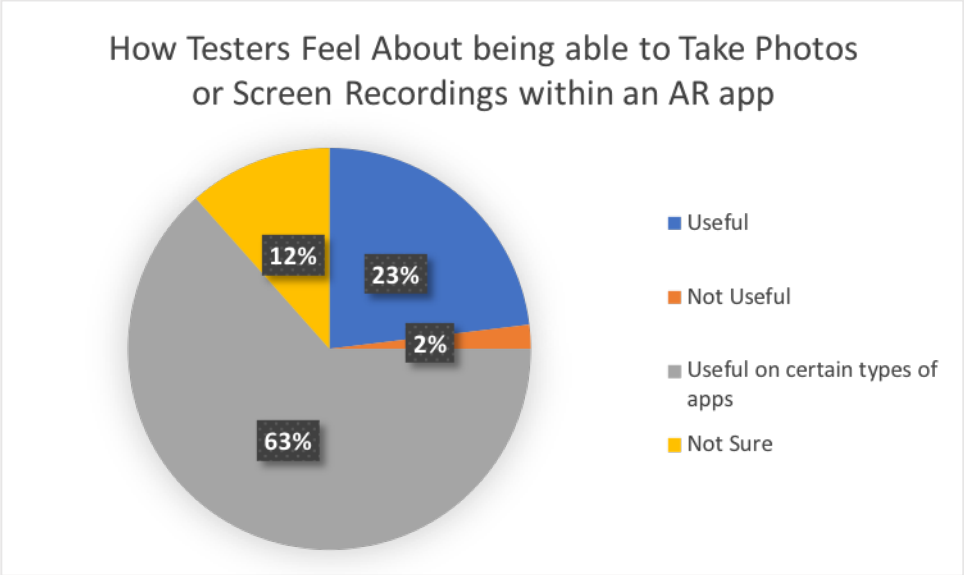

Figure 5. Full results of how testers feel about being able to take photos or screen recordings with an AR app.

If a store offered the ability to shop with AR, would you prefer it be a separate feature within the store's current app, have a separate AR app for it, or be an option that only shows up on elements that can be seen in AR? Another difference I noted on Augmented reality apps is with the shopping apps, the stores had different ways of implementing it into their store apps. I saw three different ways stores included it. The first way was creating a whole separate app from the original store's app. For example, IKEA Store is IKEA's original store app. They then created IKEA Place as their augmented reality app. The second way is making it

a feature right inside of the store's app. Amazon implemented augmented reality by including an AR view feature under an icon which looks like a camera. Last way is to add an icon on items which can be seen in augmented reality. Magnolia Market did this where they intermixed the items which can be seen in augmented reality with the ones which can't.

The results were about even between two options. 44.2% said they'd like it to be an option that only shows up on elements that can be seen in augmented reality. Then 42.3% said they'd like it to be a separate feature within the store's current app. Only 13.5% said they'd like it to be a whole separate app (see Figure 6). This isn't too much of a surprise as it takes a user time to download a whole new app. Also, when there's a whole separate app, a user doesn't get to still explore all their options. They're limited to just what they can view in augmented reality. This is also bad for the stores. If stores are wanting to implement augmented reality, they should include it somehow within their already created app. If stores or already made applications want to implement augmented reality, they should also figure out the best way to transition to it for their users.

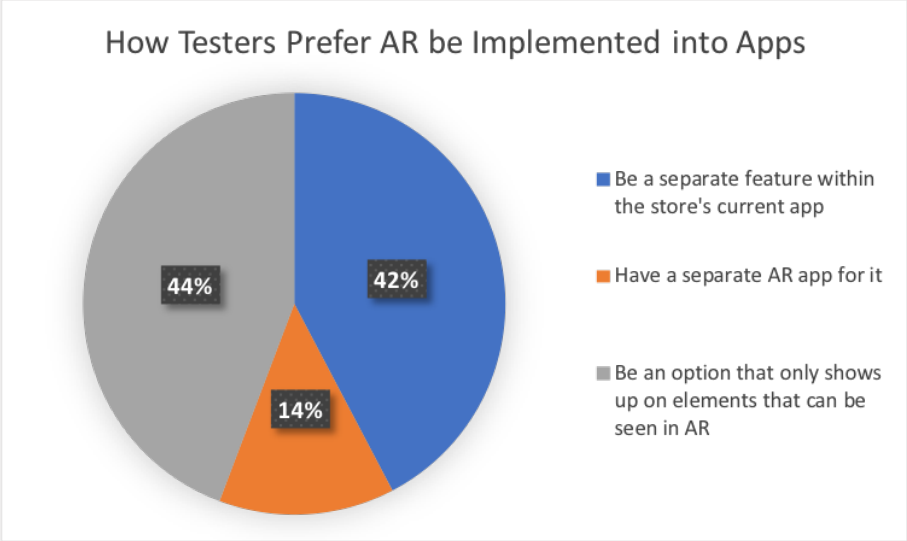

Figure 6. Graph representing how testers would prefer AR to be implemented into already created mobile applications.

Inside vs Outside

The next section of the survey went back to testing inside vs outside. I asked testers where they'd rather use augmented reality games, now I wanted to test how well an augmented reality object appeared both inside and outside. In order to do this. I selected three different augmented reality objects. I chose an element from Alice's AR quest (Figure 7), Lego AR Studio (Figure 8), and AR Dragon (Figure 9). I selected them because they were all different. Lego AR Studio had a lot of detail. Alice's AR quest was large in size. Then AR Dragon had life-like features like eyes and teeth.

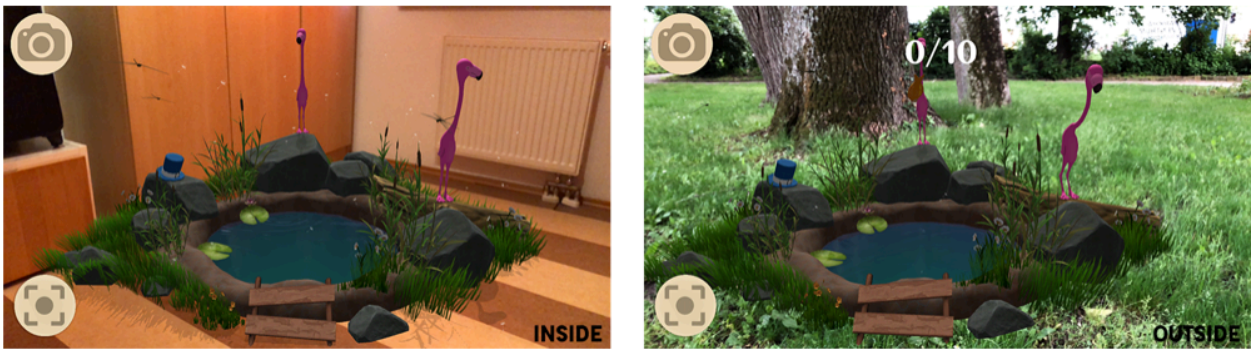

Figure 7. AR Object from Alice's AR Quest inside and outside.

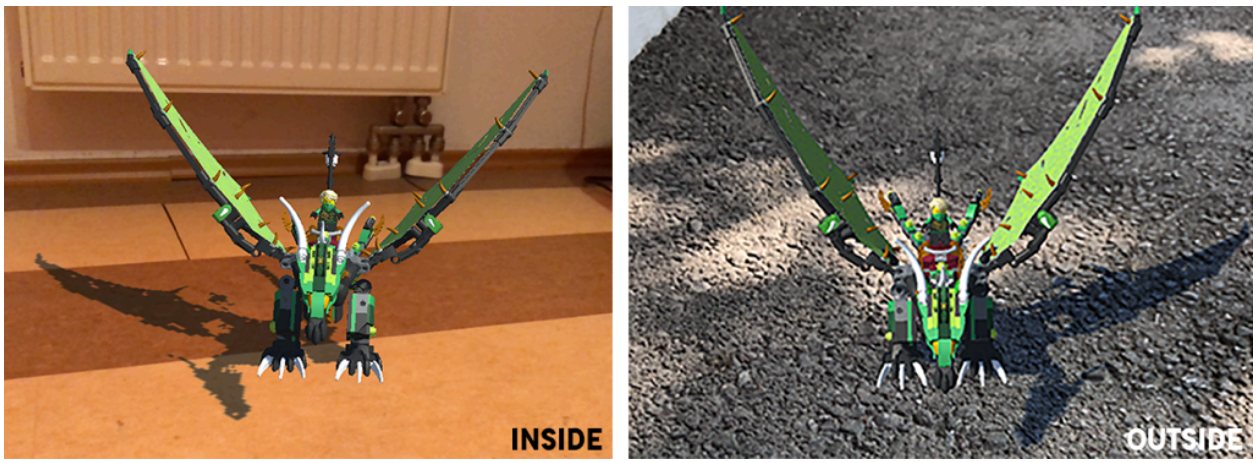

Figure 8. AR Object from Lego AR Studio inside and outside.

Figure 9. AR Object from AR Dragon inside and outside.

I took a screenshot of the elements both inside and outside. I showed the images side by side and testers could respond with the image they felt looked best inside or outside. They also had the option to choose the object looks the same inside or outside.

Each object did best outside (See Figure 10). Just like with art, an object appears more realistic when the lighting on it is correct. Natural lighting helps provide this lighting. Possible reasons the objects didn't do as well inside is because some of them were large in size. The object which got the highest score for outside was the item from Alice's AR quest. Since the object was so large, it was hard to make it fit inside naturally. The object was colliding with the drawers and closet in the room. Developers are already aware of this issue and refer to it as occlusion.

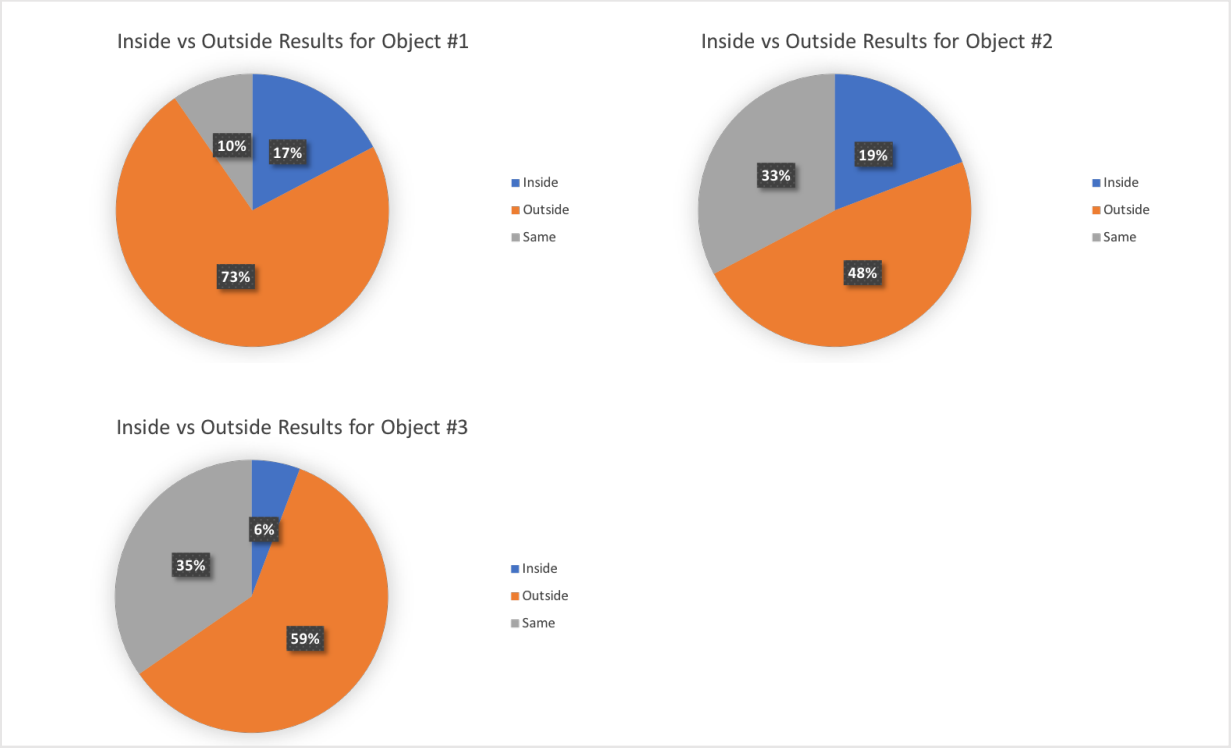

Figure 10. Graphs showing which objects looked better inside or outside.

Occlusion is basically making sure the element follows the rules of perspective in an augmented reality scene. What makes occlusion so hard is, “no AR device available today has the ability to perceive its environment precisely or quickly enough for realistic occlusion” (Mathew, 2018). There are many issues with augmented reality but from this survey we can see occlusion is an issue which should be focused on in order to create a great experience both inside and outside.

The object which did best inside was the elements from AR Dragon. The creators appear to have added their own animated lighting to the object making it look good both inside or outside. Later on, I survey how realistic a certain augmented reality object is. The objects which had realistic animated lighting on them, scored the highest.

Facial and Surface Recognition

Next, I wanted to survey the design of the facial and surface recognition patterns. In order for augmented reality apps to work, they first scan the area or face in order to know how and where to place an object. This facial recognition takes a couple seconds and usually uses a pattern to show a user the app is working. Even though an augmented reality object may look just as good as another, a user may not feel that way if they feel their face or area wasn't scanned well enough. This goes back to the design.

I tested the different designs in each category of app. Within each category, I screenshotted 3 different types of designs Figure 13 represents social apps, Figure 14 represents gaming, and Figure 15 represents shopping. I selected a design which was intricate, one with little detail, and one with no or a very minimal design style to include in each comparison. I wanted to see which of the 3 would be best.

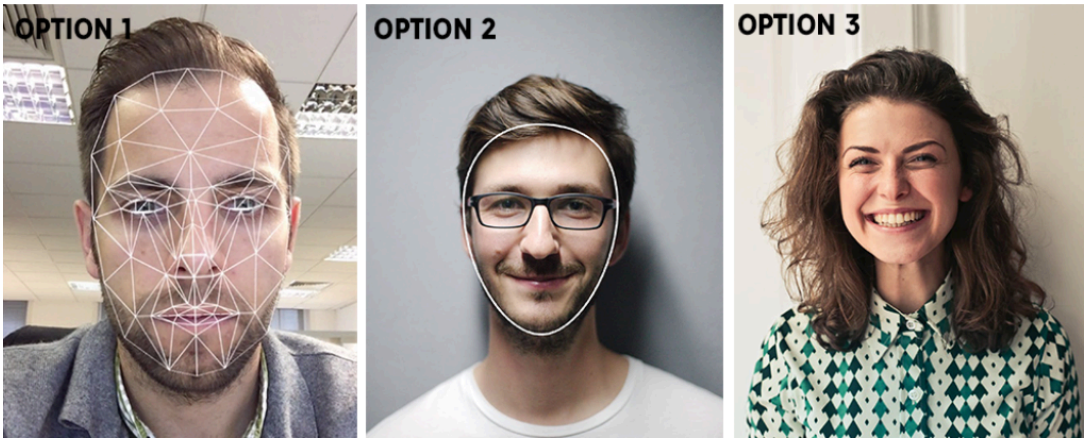

Figure 13. Different facial recognition patterns in social apps.

Figure 14. Different surface recognition patterns in gaming apps.

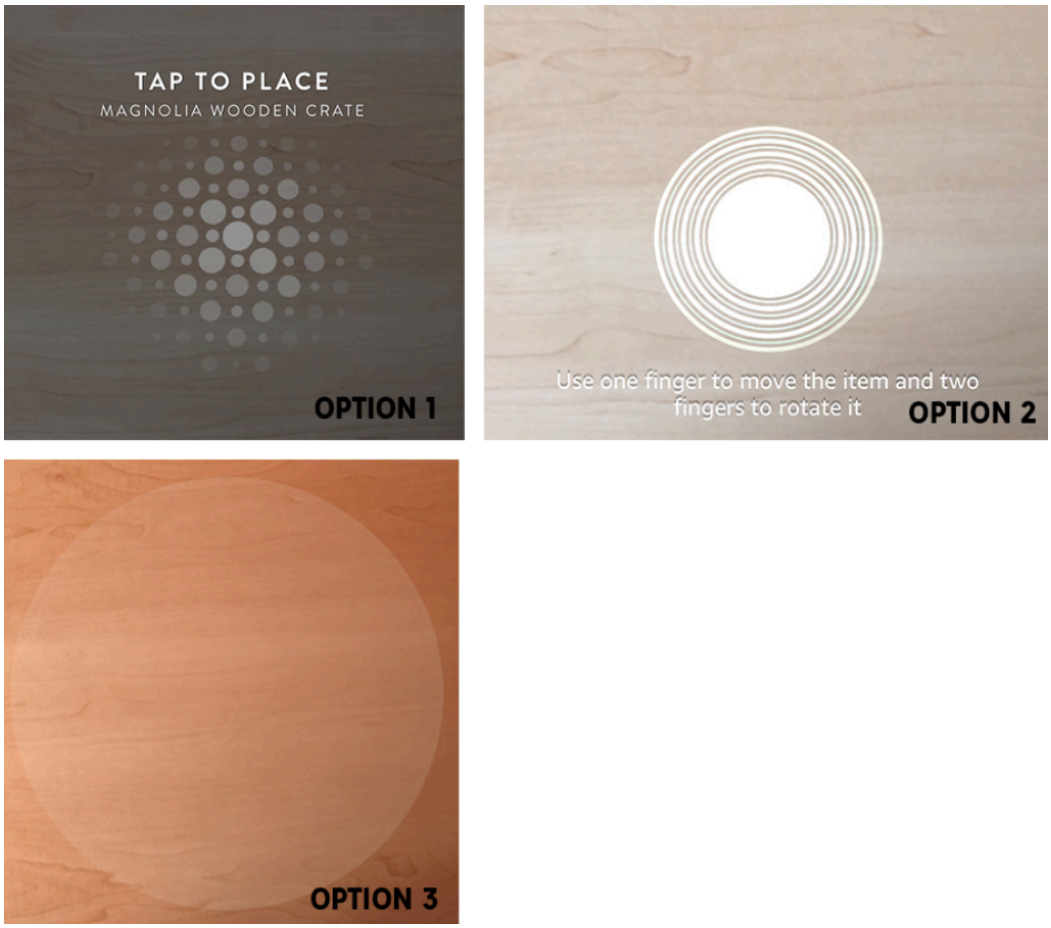

Figure 15. Different surface recognition patterns in shopping apps.

In all 3 categories, the most detailed facial/surface recognition pattern did the best (See Figure 16). This could be because the more detailed facial and surface recognition patterns appear to be covering more area. They also wrap around the area better, especially with the facial recognition. It looks more personalized to the users. For example, Snapchat has a detailed facial recognition pattern which wraps around the face rather than a generic outline. Even if the design of the facial/surface recognition doesn't add to the accuracy, it does help with users trust of the product.

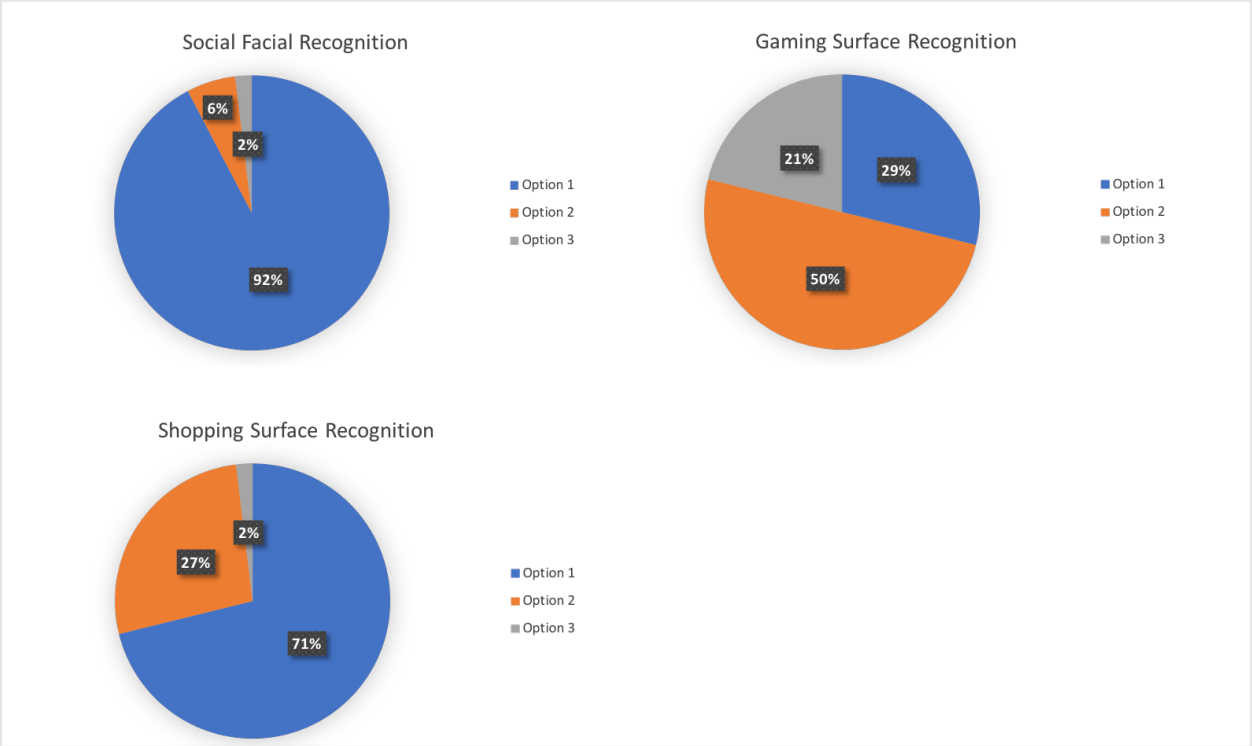

Figure 16. Graphs showing how well each type of surface recognition pattern did under each category.

Realistic Quality

The last survey section was on how realistic the augmented reality objects look. A goal of augmented reality is to help bring the virtual world into the physical. The augmented reality

object may be a fictional dragon, but it can make for an amazing experience depending on how realistic the object appears.

I focused on the shopping app elements as these need to be most realistic as people are using the augmented reality to test out clothing, furniture and cars. I chose 8 different elements. I chose elements which were different in detail, size, color, and texture. I screenshotted each element in the same room, except for the BMW iVisualizer as the element was just too big. I didn't want the fact it looked too big in the room to effect results. I had testers rate each object on a scale from 1 to 10. I list the objects from highest rating to lowest from the survey.

Object 1. The augmented reality object which did the best was a vase from Magnolia Market (Figure 17). Its average score was 8.5. It scored way higher than the other elements as the next highest scored got a 5.7. I compared it the other elements and noticed the creators of the object did a good job on its animated lighting.

Having the animated lighting as opposed to relying on natural lighting helped the augmented reality element appear more life-like. An important factor in making any augmented or virtual object to look realistic is accurate lighting. Getting the correct lighting can be hard because a develop won't know where the light source of a user is going to be coming from (2017, "5 Tips to Make Your 3D Look Real"). It would be worth time though to look into ways to solving this problem.

Figure 17. Object is from Magnolia Market and is the Highest rated AR object in looking real.

Object 2. The second-place object with 5.7 was a chair from Amazon (Figure 18). The chair is textured and is larger in size. Although it had a lot of texture to it, the lighting on it doesn't look quite right. They have the lighting coming from the front. Most rooms have lights in their ceilings though, so it'd make more sense to put the light source at the top. When creating an app, develops should think of where their user will be using the app. This will help them get a general idea of where the light source should come from.

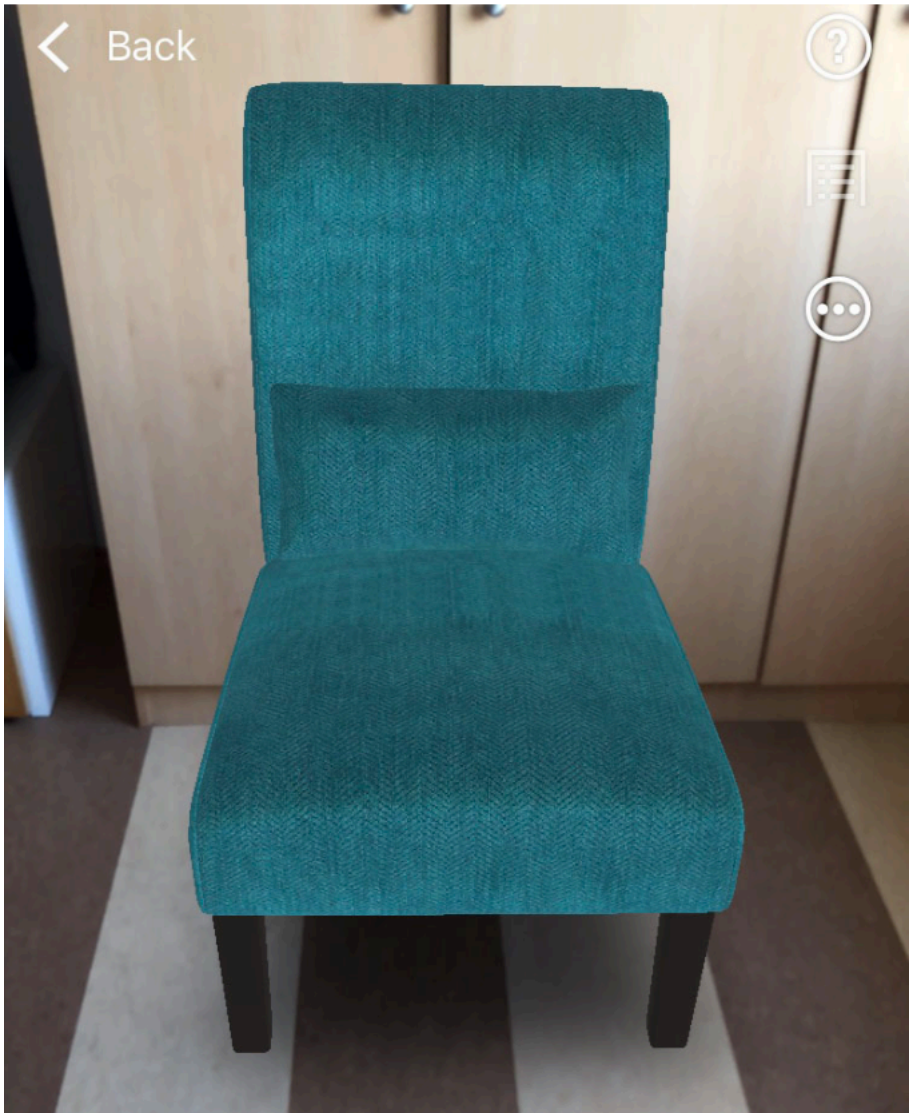

Figure 18. Object is from Amazon and is the second rated AR object in looking real.

Object 3. The third-place object was also a chair, but it came from IKEA (Figure 19). It got an average rating of 5.3, so not too far off from Object 2. This object had one color which is different from the other objects. There also wasn't a lot of texture to it. With the object just using one color but no texture is what made it score lower than Object 2. The light source comes from the top, but the surface looks so smooth it's unrealistic. Texture along with accurate lighting definitely help make for the most realistic augmented reality objects (Mammo, 2016).

Figure 19. Object is from IKEA and is the third rated AR object in looking real.

Object 4. The fourth-place object averaged a score of 5.2. The item came from Magnolia Market and is a stand (Figure 20). It's made from metal which is a different material from the other objects. It also had intricate details on it. The item has nice animated lighting but what made it look less realistic is the occlusion isn't quite right. It appears to be getting almost too narrow at the bottom. Also, on the right side it looks like it's more diagonal, so it looks lopsided.

Figure 20. Object is from Magnolia Market and is the fourth rated AR object in looking real.

Object 5 & 6. There was a tie for fifth-place between a BMW from BMW iVisualizer (Figure 21) and a vase from Magnolia Market (Figure 22). Both got a score of 5.1. It wasn't too surprising the vase scored lower because it has jagged edges. The lighting on it is also off. The jagged edges and bad lighting make it easy to tell it isn't a real object. The BMW though was surprising. It may look almost too perfect to testers which is why it scored lower. Also, the animated lighting appears off because it's in the shade.

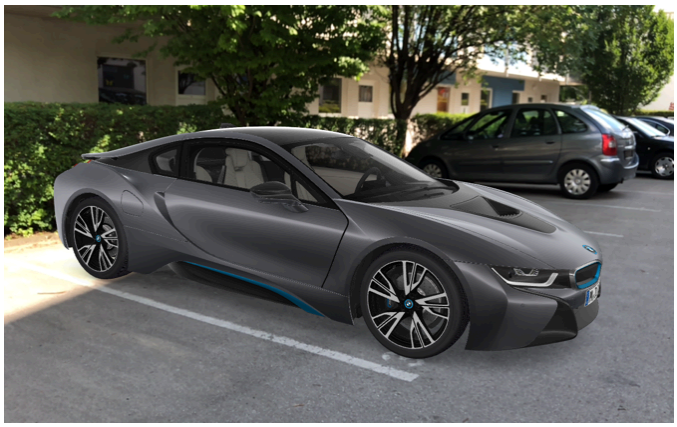

Figure 21. Object is from BMW iVisualizer and tied for fifth with object in Figure 22.

Figure 22. Object is from Magnolia Market and got fifth-place with Figure 21.

Object 7. The sixth-place object was a dress from FittingRoom (Figure 23) with a score of 4.3. What I notice from this element is again, the surface is too smooth for a dress. The dress has these stripes on it but they're just lying on the dress flat. There's no dimension to them. It also appears stiff rather than falling naturally on the mannequin. Also, when you look closely, the edges have an imperfect black dotted line going around it.

Figure 23. Object is from FittingRoom and is the sixth rated AR object in looking real.

Object 8. The object which scored last is a storage container from IKEA (Figure 24). It scored a 4.1. This object was probably hard to design as it has extremely thin lines. These lines were probably hard to add lighting to as there doesn't appear to be any on it. Also, the lid for the container just looks like a flat white circle with a darker oval shaped circle for the handle. The design is flat and lacks texture and lighting.

Figure 24. Object is from IKEA and is the lowest rated AR object in looking real.

Conclusion on realistic comparison

The objects which did the best were the ones which did well on lighting, occlusion, and texture. Designing for augmented reality objects is hard because with the lighting, a designer never knows where the light source is going to be. Then with the occlusion, it's hard for a designer to make a perfect map for every type of room. Lastly, texture is hard to design for because it's very detailed. Though these elements are hard to nail, they're worth focusing on finding ways to improve because they are what make the difference between a realistic augmented reality object and an unrealistic one.

Quantitative Testing

After I did the survey, I began the quantitative testing. For this I looked at the effects of augmented reality apps on the iPhone's battery life, loading time, and data usage. I tested the effects on battery life and loading time both on and off Wi-fi, then I tested the data usage off Wi-fi. I played with each app 3 times both on and off Wi-fi for a total of 6 times. I did this to help reduce the chances of the results being a fluke. I then used the storage space of each application as a point of comparison. This is because larger file sizes have been known to take longer to load and use up more energy. Creating 3D models can result in large file sizes (Fernández-Caramés, Fraga-Lamas, Suárez-Albela, & Vilar-Montesinos, 2018).

This is evident when you compare the average augmented reality apps file sizes to the average regular app file size. The average app size for an iOS is 38 MB. The average size for a gaming app for iOS is 67.7 MB ("Average App File Size: Data for Android and iOS Mobile Apps", 2017). The average file size of all the augmented reality apps I tested is 238.44 MB and the average size of the AR gaming apps being 349.44 MB. This is quite a huge difference.

Although files get to a point where they can't be any smaller, developers would be doing a great service to users if they could do all they can to minimize their file size. Especially for those users who have smaller storage spaces on their devices. Users are "likely to become more conscious about what apps to keep and what to uninstall, so the developers' bar to impress will be getting even higher than it is now" (Mlot, 2012) Especially when file size has the potential to also effect the phones battery life, loading time, and data usage.

Loading Time

Getting the file size of each app was the first step I did before beginning testing. I then started testing the loading time. I used a stop watch and right when I'd tap the application, I

would start the timer. I would then stop it once everything that was meant to show on the home screen appeared. The results were quite interesting. For the most part, the loading time for the apps were around the same range. There were two apps though, Pokémon Go and Lego AR Studio, which took a much longer time to load than the others. IKEA Place also took a little longer but was still below 10 seconds (see Figure 25).

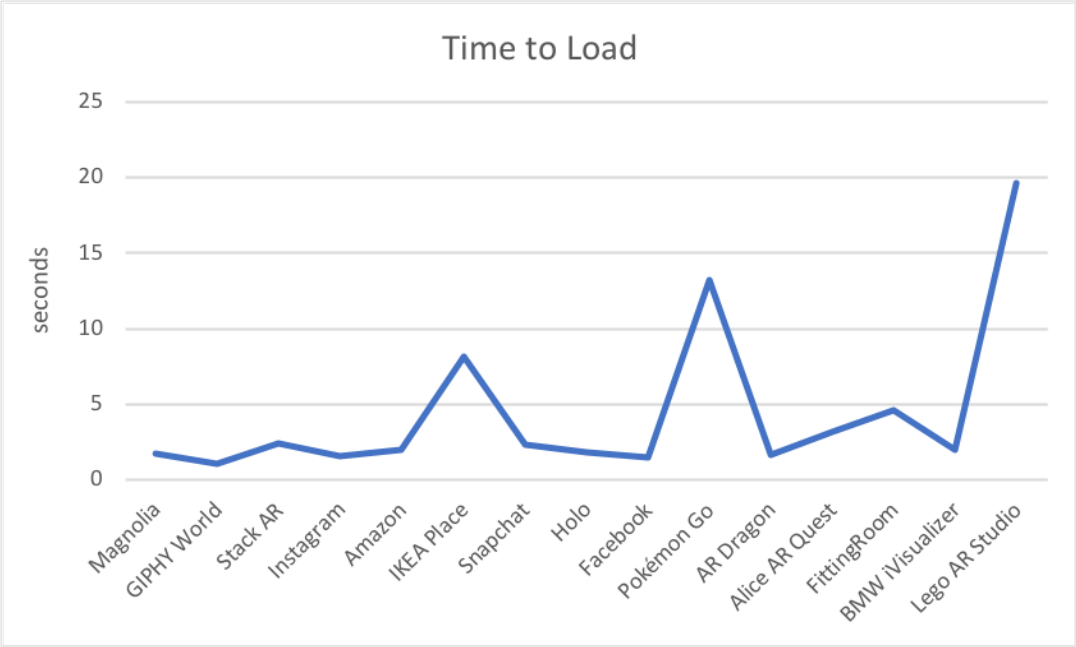

Figure 25. Graph representing how long each app took to load on Wi-Fi.

I couldn't find much info on why loading time differs from app to app. With my background in UX design, there's a couple reasons those two could have taken longer than the others but it wasn't necessarily because of the file size. All the other apps had a range between 1.05 to 4.63 seconds. Some of the apps which were larger in file size were faster than the others with smaller file sizes.

I also did the same test on the loading time using data instead of Wi-fi. Majority of apps took a little longer to load than when they were on Wi-fi. The ones which took longer may be

due to the fact the Wi-fi had a bad connection during the 3 tests. Same results occurred where the file size didn't appear to affect the loading time (see Figure 26).

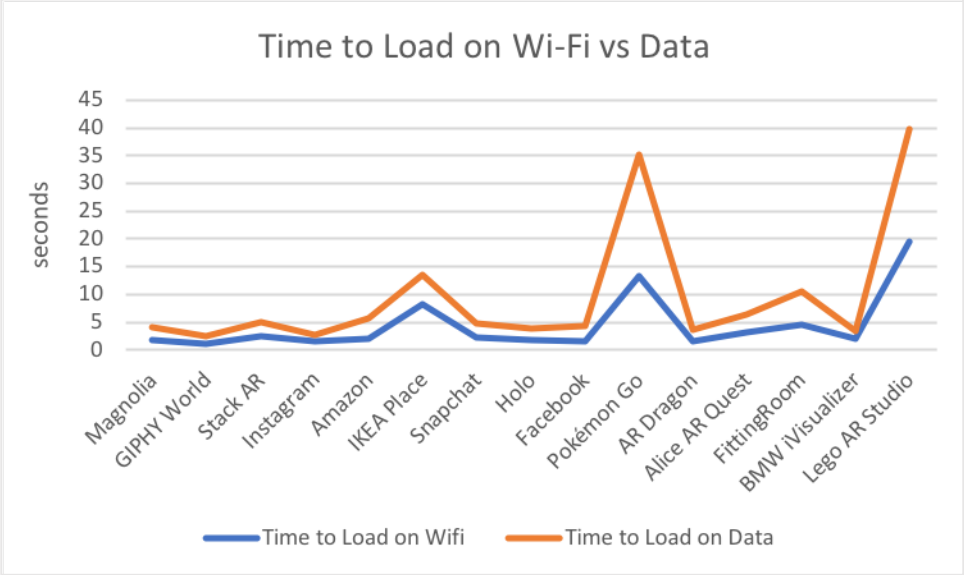

Figure 26. Graph comparing how long each app took to load on Wi-Fi versus data.

Battery Usage

After I tested the loading time, I looked at the battery usage. I recorded the battery life before I opened the app then once each app loaded, I started a stop watch I had set for 10 minutes. Once the 10 minutes were over, I subtracted the starting battery life from the final battery life. After I played each 3 times, I averaged the results and compared them.

It appears file size may be a contributing factor to a mobile devices battery life draining. The larger the app, the larger the decrease in battery life. The smallest decrease was with Magnolia Market where it just decreased the battery by 3.7%. This means a person could play the app for about four and half hours before their phone died. This may not be a big deal with a shopping app as a user is probably using the app at home where they can easily charge it.

The highest decrease was with Lego AR Studio with a decrease of 8.6%. Which means a user's phone would die in less than two hours. With gaming apps, especially the ones where they

require a user to go outside and explore, this is going to be frustrating. This was an initial problem actually for Pokémon GO. Players right away noticed how quickly it was draining their battery and they weren't happy about it (Hollister, 2016). From my testing, it appears Pokémon Go has managed to decrease their battery usage to 4%. Much better than Lego AR Studio. Augmented reality apps don't have to suck the battery life out of user's phones (see Figure 27).

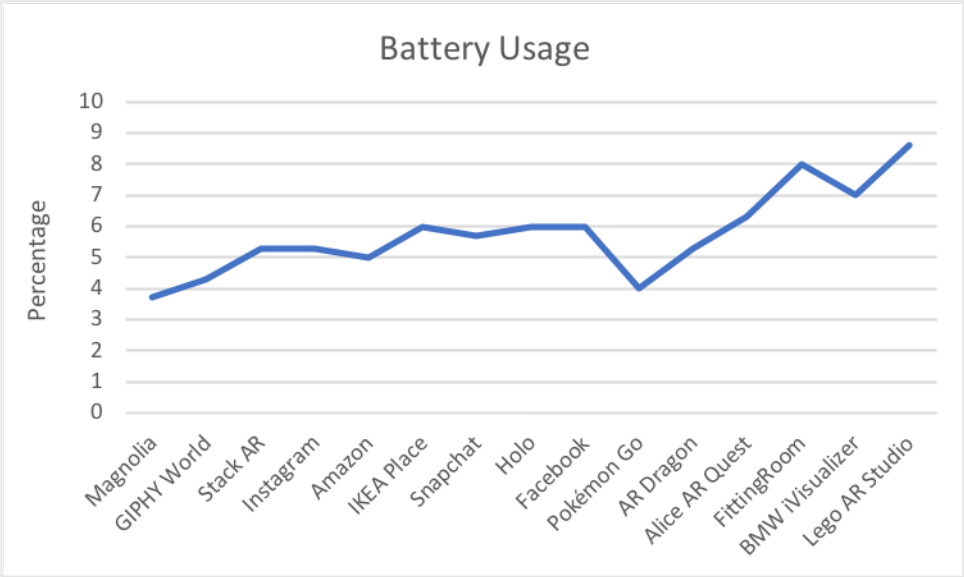

Figure 27. Graph representing how much battery usage each app took on Wi-Fi.

Just like with the loading time, I also tested the battery usage using data instead of Wi-fi. Using the apps off data did use more battery life and also followed the same pattern as when they were on Wi-fi. This is another important note for the apps which require a user to be outside. If a user is outside, they most likely aren't going to have Wi-fi. Looking back at Lego AR Studio, its battery usage went up to 10%. This means off Wi-fi a user could only play for an hour and forty minutes (Figure 28). There definitely should be continuing research into how to lower an apps file size in order to prevent apps from killing user's phones in less than two hours.

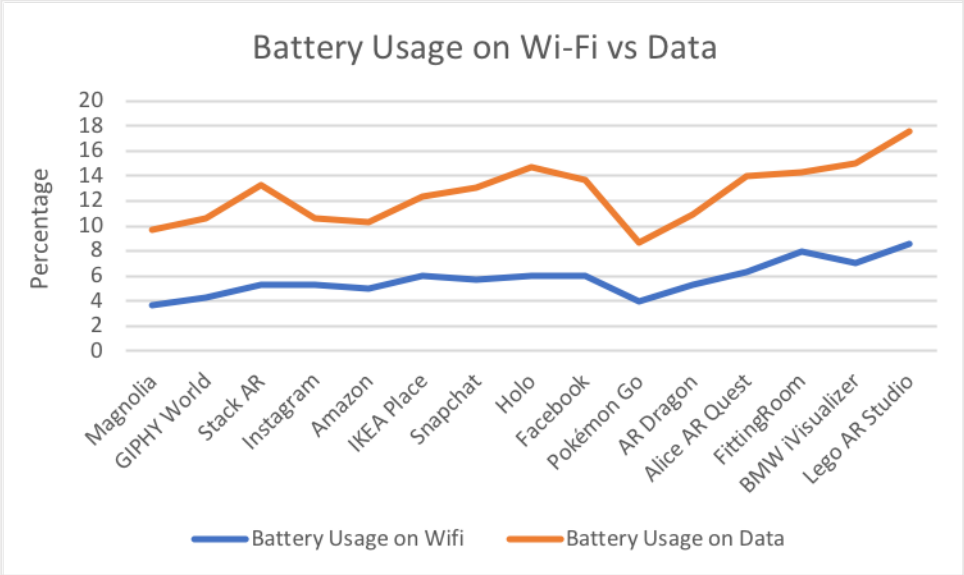

Figure 28. Graph comparing battery usage on Wi-Fi versus Data.

Data Usage

The last test I did was seeing if the file size effected the data usage. Same concept I did with the battery life. I recorded the data usage the app had already used. Then after playing the app for 10 minutes, I closed the app and checked how much the data usage went up. The results showed file size doesn't affect the data usage (see Figure 29). There's other factors which cause an app to use less or more data.

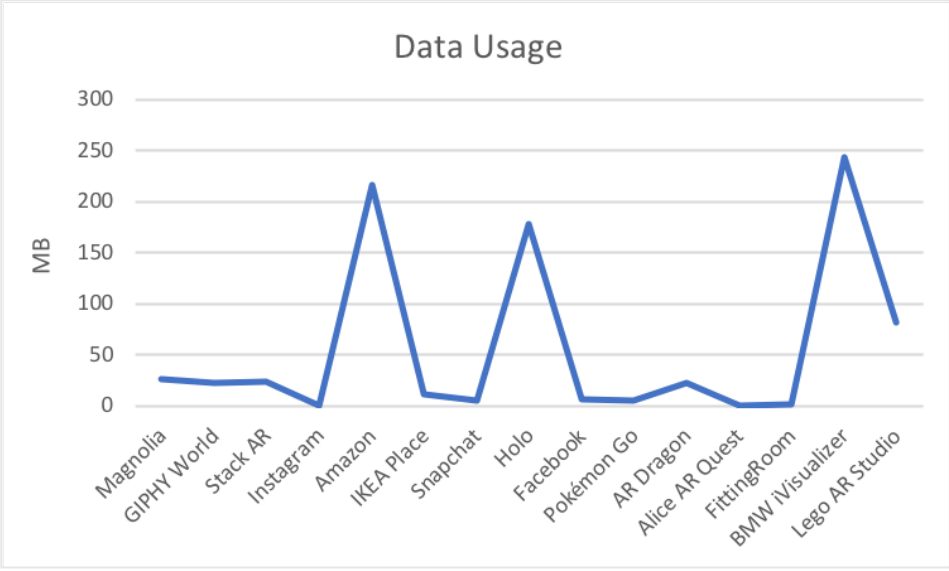

Figure 29. Graph representing how much data was used with each app.

It's reported the biggest guzzlers of data usage are gaming, social, video chatting and video and music streaming apps (Ashpari, 2012). They may need to add shopping apps to this list as they averaged the highest data usage score out of the other 2 categories. It seems some apps have nailed down how not to use so much data while the others need to work on it.

Conclusion for Quantitative testing

Sometimes creators can get fixated on other details like how the game looks and different features which should be included they miss other important factors to making a great app. Players loved Pokémon Go when it came out and loved how they could see Pokémon virtually in the real world. It was like living a lifelong dream of becoming a Pokémon trainer. The players excitement though was interrupted by the application killing their batteries and using up data. Pokémon Go has definitely improved and other augmented reality apps need to follow their example.

Additional Notes

Since I experienced each app for a good hour, I noticed some additional features and qualities I didn't notice the first time when creating the survey. These additional notes could be used for additional testing or good guidelines for future developers to think about.

Feedback

In Alice AR Quest, a user can walk through the "looking glass" and enter into Alice's world. I noticed while playing the game inside, it was sometimes difficult to complete tasks because I had a restricted walking area. When I tried to trick the game, it caused a glitch where the phone thought I was still moving even though I was standing still. Playing inside ruined the apps perception of where I actually was.

Another problem was sometimes when I touched a game piece, it wouldn't react right away. I would tap the object a couple times thinking it didn't register and then I realized it was just lagging. This is a good design practice where developers should always make sure there's immediate feedback to whenever a user does something. It lessens confusion and frustration.

Surface Recognition

I mentioned earlier how developers should try and make objects shrink to fit a user's space. Stack AR is nice because as the stack gets taller and taller, rather than part of the stack getting cut off, they have the tower shrink. This way everything continually fits onto the screen.

What was difficult with the app though is it was hard for it to detect the surface. I got frustrated a couple times because it was taking me longer than normal to get the app to detect surface. There also was no feedback. Some apps have a way to tell a user if it's able to detect the surface or not. With Stack AR I was clueless. I had no idea if it was or wasn't detecting the surface. I just had to play around until I got it to work.

Amazon was almost too fast. I'd point the phone at a surface and the object would appear. This seems nice, but it could cause frustration if a user wanted the object in another location from where their phone was pointed at. Sure the user can move the object, but it takes additional effort which wouldn't be needed if the user could choose when they want the object to appear.

AR Dragon was nice because it gave feedback on how it was doing detecting the surface. It was also nice because all I had to do was tap a button to make the AR object appear rather than waiting for the app to decide. I could see this being good or bad. It could be bad because a user will be impatient and just tap the button for the AR object to appear and then get frustrated later on when the object doesn't appear right on their screen. I feel allowing a user to put the AR

object in by tapping a button is a good idea but should only be allowed once enough surface has been detected. So there should be feedback given to a user for how well the surface has been detected and once it reaches a certain point, a button can be tapped to bring in the augmented reality object.

Last note on surface detection, I enjoyed how in IKEA Place the augmented reality element would fall onto the surface. It helped give the illusion it was really in the room and the surface was detected properly.

Surface detection is one of the first interactions a user will have with an augmented reality app. It is important for developers to make sure it gives feedback to users and give the illusion the object is really in their surroundings. Surface detection is just a small portion of the user experience but since it's one of the first experiences, some testing should definitely be focused on it.

Further Research

From my study there's further testing which should take place. My study also shows areas which are more important to test out over others when it comes to the user experience. From my testing, we know users prefer if companies with already made apps implement the augmented reality into their previously made app rather than having to download a whole new one. Additional testing should be done on how companies can transition their customers to actually using the implemented augmented reality. A company doesn't want to spend time investing in adding augmented reality if their customers aren't going to know how to access or know how to use it.

There should also be more research done on how to stop augmented reality apps from draining batteries and using up too much data. Some of the apps have figured it out but many of

them haven't. Further testing could be done on what exactly is causing the battery to drain faster and more data to be used than another. This will be extremely beneficial to developers.

Lastly, more testing should be done on the layout of augmented reality apps. If I had more time I would definitely want to get more into this. Augmented reality apps have new features and abilities. They'll require different layouts and new icons. Further testing should be done on best layouts for augmented reality apps which will allow a user to learn the new features quickly and make the most of augmented reality.

Final Conclusion

There's a great quote from Sam Walton, who is the creator of Walmart, where he said, "There is only one boss. The customer. And he can fire everybody in the company from the chairman on down, simply by spending his money somewhere else" (Reiss, 2014). The same could be said for the development of augmented reality.

Users are the boss when it comes to technology being able to be developed or not. They're the ones who use the actual products. If users find they aren't having a great experience with augmented reality, they'll stop wanting applications which use it. There's a need for more user experience type testing to be done of augmented reality apps. There's already been a lot discovered from the testing done through the competitive research. The top discoveries from the research being:

1. There's an audience of users which like playing augmented reality apps inside and outside. There just needs to be further testing done on each type of user and what they want to get out of the apps.
2. For designers of augmented reality objects, they should be focusing more on the lighting, occlusion, and texture to make their object more life-like.

3. The more detailed the surface/facial recognition pattern is, the more a user will trust in its abilities to map out the surface or face correctly.
4. File size doesn't affect loading time necessarily, but it may be the cause of batteries draining quickly and more data being used.

Users being able to more easily access augmented reality is a great opportunity for more user testing to be done. Developers of augmented reality, whether they are creating for a device or a mobile app, should take note of their user's needs and wants. Otherwise, augmented reality will become just a gimmick of the past. Augmented reality and the field of User Experience have grown together, and now they need to be combined to help augmented reality reach its full potential.

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