Augmented Reality for City Planning

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Abstract. We present an early study designed to analyze how city planning and the health of senior citizens can benefit from the use of augmented reality (AR) with assistance of virtual reality (VR), using Microsoft's HoloLens and HTC's Vive headsets. We also explore whether AR and VR can be used to help city planners receive real-time feedback from citizens, such as the elderly, on virtual plans, allowing for informed decisions to be made before any construction begins. In doing so, city planners can more clearly understand what design features would motivate senior citizens to visit or exercise in future parks, for example. The study was conducted on 10 participants 60 years and older who live within 2 miles from the site. They were presented with multiple virtual options for a prospective park, such as different walls for cancelling highway noise, as well as benches, lampposts, bathroom pods, walking and biking lanes, and other street furniture. The headsets allowed the participants to clearly visualize the options and make choices on them. Throughout the study the participants were enthusiastic about using the AR and VR devices, which is noteworthy for a future where city planning is done with these technologies.

Keywords: Human-centered computing · Visualization design and evaluation methods · Augmented and virtual reality

1 Introduction

There is a novel and rapidly expanding phenomenon taking place as augmented reality (AR) and virtual reality (VR), henceforth referred to by their acronyms, are rapidly taking over a myriad of sectors from the entertainment and game industry to architecture and medical training. According to the International Data Corporation, worldwide spending on AR and VR is projected to increase by 68 percent in 2019 from 2018 [10]. Another area which could greatly benefit from the introduction of these technologies is city planning, in particular when it comes to catering to the needs of senior citizens. By 2030, there will be 72.1 million elderly Americans over the age of 65, with 750,000 of them residing in Miami, FL, which is known to have the highest percentage in the entire

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US [2]. According to the Center for Disease Control (CDC), seven out of ten deaths among Americans are from chronic diseases, and nearly one out of every two adults has at least one chronic illness, many of which are preventable. The National Prevention Strategy proposed by the CDC recognizes that good health comes not solely from receiving quality medical care but also from mitigating a disease before it starts, such as through healthy exercise in open areas and parks, provided by effective city planning.

We present an early study designed to analyze how city planning will benefit from the use of AR and VR, making it more efficient and accurate in catering to the needs of people such as senior citizens. In the study, AR and VR help to understand what elements would make the participants more willing to exercise in a specific area of Miami, if such elements were to be constructed. This area is referred to as "M-path," which is an underutilized zone in Miami, FL, that lies under Miami's elevated Metro-rail transit system and passes through several inner-city neighborhoods, where a large population of senior citizens is located and is known for its heavy vehicular traffic.

1.1 Contribution

Improving the health of senior citizens is a pressing issue, with cities needing to adapt and plan adequately to cater to their growing needs. This study introduces a novel way to address this issue by introducing a groundbreaking technology to enhance a city's planning efforts. As far as we were able to search, no work has combined city planning with AR at full scale, let alone to use it to influence planning decisions to improve the health and accommodation of citizens. Most importantly, the biggest contribution is that this type of study with these technologies is feasible and provides a path forward for other researchers to pursue similar avenues of study.

2 Related Work

2.1 Health and Safety

While there is no direct research that has explored city planning to improve senior citizens' health, there have been similar attempts to improve health in general through AR and VR. For example, Ha-na et al. performed a study to improve balance while walking and running to help avoid falls for 21 elderly women with 10 doing the Otago Exercise Program with VR and 10 doing it without the VR [12]. The study found that the women that completed the exercise program with the VR increased their mobility and physical activity more than without it. Hence, it provides some initial insight as to how these enhanced reality technologies can improve health instead of harming it. Basing it upon Microsoft's Kinect software, virtual reality has also been used to make the RemoviEM system and has proven to be successful for rehabilitation for people with multiple sclerosis as seen in [9], using aerobics and strength training. The personalized rehabilitation exercises the software included with the VR proved to help the patients more than the traditional exercises, which corroborates with Ha-na et al on the fact that VR/AR can be an effective option in improving health.

AR technology has also been used to increase outside physical activity. The software called "HybridPLAY" [5] is a prime example of this. With this application, users could attach a sensor to playground equipment to be able to use the equipment as an input to their phone to complete mini-games. They found that the use of such games increases the likelihood of users going to a park or outside to exercise. Another example can be seen in a 2019 study using "Pokemon go", a mobile AR game where users walk around outside trying to capture small creatures which can be found at various locations throughout a city. Hino et al. found that older users of this game had much higher step counts at the end of 7 months than non-users [7]. Furthermore, Yang et al. conducted a survey of apps that implemented behavioral change techniques specifically for physical activity [11]. They found that the most successful apps used a combination of social support, demonstrations of the physical activities, and instructions on how to perform the activity which can suggest that these apps can provide a low-cost intervention that could help increase a user's physical activity. If people have easy and quick access to ways in which they can be more active, then the probability of them engaging in this lifestyle increases.

Additionally, VR and AR technologies have been shown to improve overall safety as noted in the study by Schall Jr. et al. [8]. They studied how to evaluate the effectiveness of AR cues in improving driving safety among 20 elderly drivers with cognitive impairments [8]. This system provided cues as the subjects drove with primary targets such as cars or pedestrians and secondary targets such as dumpsters or barrels. Drivers responded favourably when pedestrian and walking signs where shown with the AR technology as it made it much more clear to them, decreasing their risk of getting into an accident.

2.2 City Planning

Due to how recently the AR technology has been adopted, limited research has supported city viewing or planning in this way. For example, Zhang et al. used the Microsoft HoloLens to visualize the City of Toronto, Canada [13]. Even though the visualization was of a miniature model on top of a table, it shed light on the potential of applying AR to city planning, as entire buildings, roads, parks and more could be visualized and modified before actually being constructed. On the other hand, Claes and Moore used AR to increase awareness about local issues around a city [6]. Their study, while limited to a single location, did provide interesting reactions by the locals, such as curiosity, personal reflections, social interactions, and perceptional changes, among others [6]. In a sense, the novelty of AR on its own helps to increase interest and public engagement when it comes to city planning and other applications.

3 System Design

3.1 First Iteration with VR

Fig. 1. Virtual reality environment (first iteration)

In the first iteration of our testing environment, we created a VR space that simulated the future park, as shown in Fig. 1. While this was a great way to design and test in the lab, it was difficult to have senior citizens come and experience the site with the modifications that were made. The participants would have needed to travel to the lab to see the VR mock-up before going to the site, which would have a large time-gap in between and would defeat the purpose of real-time feedback from the participants. The environment only being available in the lab also meant that the participants could forget or misremember what they saw afterwards, skewing their opinions on the different elements for the park. In addition, given the participants' age group, additional precautions needed to be taken in order to simulate walking through the park's path, which had the consequence of making the walk feel less natural for them. While this may still be a possibility in the future, we decided to use a different approach.

3.2 Second Iteration with AR

Our second iteration consisted of an augmented reality environment with the use of the Microsoft HoloLens headset. In order to understand what future elements would take for senior citizens to exercise in an area with heavy bicycle and car traffic, we decided to analyze how AR could be used for them to see the changes superimposed directly on the site and give real-time feedback on said changes. In particular, we decided to focus on receiving feedback on three different types of walls for the future park. The Microsoft HoloLens was selected due to its transparent and holographic features that allow users to see virtual objects, while simultaneously being able to see the real environment around them. Note that we are using the term "holographic" loosely here to indicate virtual objects in an augmented reality environment which can only be seen through the headset. We received positive feedback regarding the HoloLens itself, with the participants being quite enthusiastic in using it. The use of AR allowed the participants to walk through, see and experience the site with all the virtual modifications, giving them a detailed look at how the environment could look in the future. In order to create the environment, we used the Unity Game Engine developed by Unity Technologies [4], which provided a streamlined and powerful toolset to develop projects for AR applications. In addition, we used 2D and 3D modeling software, such as Adobe Photoshop [1], Paint 3D, and Google SketchUp [3], as well as incorporating Microsoft's Mixed Reality Toolkit with settings that are designed specifically to support the HoloLens.

Prior to calculating the correct measurements of the site, we began to build a draft of the park design in Unity and started to create the 3D models. However, it was crucial that we understood who our targets were, which in this case were the senior citizens. In this iteration, the augmented reality environment we created included several extra models that were soon taken out, such as exercise equipment, water fountains, palm trees, rocks, bushes and decorations which made the virtual environment more appealing. However, we found that the large amount of virtual objects tended to be overwhelming to the HoloLens wearer. When using the AR headset at the site with all the elements, it became evident that there were too many real objects already surrounding the area, and the participants could get confused or distracted from focusing mainly on the three different types of walls and main street furniture. Our goal was to make the interface and experience as user-friendly as possible, which is why we decided to mark their gaze with a purple dot to make it clear to the participants where they were focusing (see Fig. 3). This design tactic as well as physically going to the site allowed us to gain the necessary insight for our next iteration.

The more detailed virtual environment we created in Unity was based upon actual measurements collected on site and the problem areas that were identified by the city and researchers, which included the following: lack of places to sit, lack of safety, noise from the highway, no clear path for walking or cycling, darkness at night, no nearby places to use the restroom and the overall unsafe atmosphere of the area. We had several meetings with people from Florida International University's School of Architecture and School of Physical Therapy to help us finalize the street furniture that would address those problem areas. We built three separate scenes in Unity, with each including lamp posts by the path to help illuminate it, separate pedestrian and cyclist lanes, signage/way finding, either a small wall, a tall wall, or a glass wall to separate and minimize highway noise, benches to rest, and bathroom pods as seen in Figs. 2 and 7. All of the distances and positioning of the elements relative to each other were accurate to the measurements we took, with the elements being placed relative to the real path in the site. This allowed for the objects to remain accurately fixed in their spatial location as the participants moved around and walked by them, being able to see them from several angles, such as how the post signaling the bike and walking line is seen from different distances in Figs. 5 and 3. The final environment can be seen in Fig. 4. Note that the wall seems to be floating above the ground as the image was taken using the HoloLens capture software, which has a different perspective than the headset's wearer. However, to the participants the objects appeared in their correct locations, allowing them to experience the wall and surrounding street furniture as intended in real-life scale and distance.

Fig. 2. Lamppost in AR

After the deployment of the three different scenes to the HoloLens and the testing done on site it was found that some of the models had colors that were too dark. An example of this was the benches that had a dark brown color which had to be adjusted to brighter and lighter colors so that the holograms were more visible in daylight with the headset. The current iteration of the HoloLens thus seems to have issues rendering dark objects in a well-lit environment, but it is very likely that this will be corrected or improved in subsequent versions (Fig. 6).

Fig. 3. View from AR with gaze tracking purple cursor

Fig. 4. Environment in AR showing the glass wall scene

Fig. 5. Biking and walking sign in AR

Fig. 6. Walking and biking lane separator in AR

Fig. 7. Floor signs in AR

3.3 Third Iteration with AR

Our third and final iteration had finalized scenes for both AR and VR environments. In order to address visibility concerns due to the limited field of view of the HoloLens, along with some participants having difficulty seeing, we used the HTC Vive VR headset, which would allow the participants to become more immersed into the fully virtual environment and understand all of the new elements that would be added without interference from existing objects in the site. Note that we added the HTC Vive in addition to the Microsoft HoloLens to add another dimension to the visualization of the park. The VR headset was only used from a stationary viewpoint and not to walk through the environment. This is explained further in the next section.

4 Experiment Design

For this pilot study, 10 elderly adults who live within 2 miles of the "M-path" near the Miami Metro-rail Station participated. The participants were required to be at least 60 years old, be English or Spanish speakers, be able to walk independently without any walking aids, have no lower limb surgery or injuries from falls during the previous 6 months, and pass the Mini-Cog test[1]. The study took place at the "M-path". All participants received an explanation about the study's goals and procedures and were given the opportunity to ask and receive answers to any questions they had. After the explanations, they were asked to read and sign the informed consent form in their preferred language and were given thirty dollars for their time and contribution.

[1] See https://mini-cog.com/.

4.1 Preparation

The participants were fitted with Inertial Measurement Units (IMUs), from the MTw Awinda system from Xsens Technologies, to assess their gait and balance during testing. This was done to ensure the AR or VR headsets would not have a negative impact on their mobility. The IMUs were attached using Velcro tape to the participant's legs, torso, arms, and head through a headband. During testing, the participants walked along the existing path on the site with the equipment. A control experiment was also conducted as a simple walk-through without the headsets (neither the HoloLens or Vive). The first part of the experiment involved assessing their balance while standing still and getting accustomed to the AR and VR experience. Hence, after confirming that the IMUs were not disrupting the participants mobility, they were asked to stand on a force plate for 30 s to measure their balance, cross-referencing the force plate with the MTw Awinda system for calibration. The HoloLens was then placed on the subject powered off and their balance was measured for 30 s, as seen in Fig. 8. Following this, the HoloLens was turned on and prepared for the participant with the tall wall scene and the participants balance was taken again. Then, the Vive was used with the participant standing to allow them to first fully see the entire virtual environment with no external distractions. This way they would know what new elements were going to appear on the AR environment mixed in with the real world (e.g., lamp posts, benches, bike lanes, line separations, and more). While they were using the VR headset, the balance was also recorded for 30 s. Note that at this point of the experiments, subjects were not walking.

4.2 Walk-Through

After the previous steps mentioned above were completed, the participant walked four times in the given path using the HoloLens headset with someone following right behind them for safety purposes. It was of particular importance to maintain a natural walking condition while having someone close to the subjects in case they fell due to loss of balance, especially as the AR experience was completely new to most participants. While the participant was walking, measurements were taken with the IMU's software. The experiment began with the HoloLens placed on participant's head while turned off and included the following conditions with each condition being randomized.

– HoloLens on with short wall scene.
– HoloLens on with tall wall scene.
– HoloLens on with glass wall scene.

4.3 Participant Response

At the end of the experiment, the participants were asked to rate how much each wall contributed to the environment on a Likert scale (1–5), with 1 being "Dislike very much" and 5 being "Like very much". Most responses about the virtual

Fig. 8. Balance test with the HoloLens

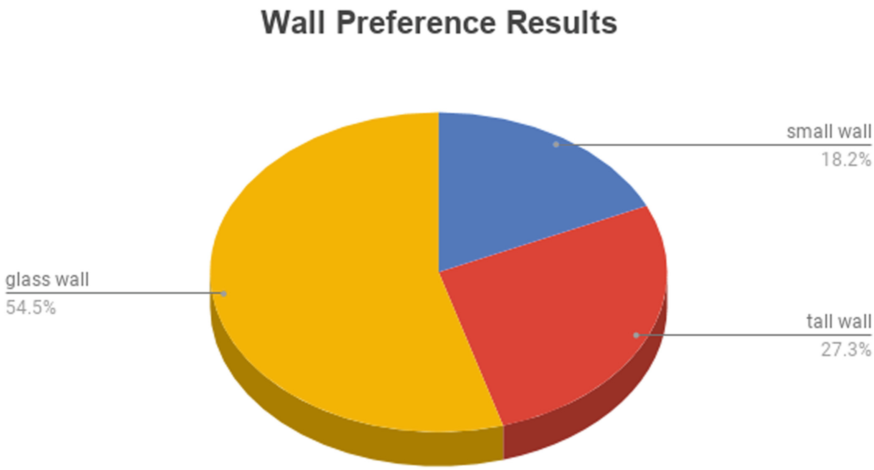

Fig. 9. Percentage of participants that gave the wall a rating of 5/5 with 5 being the highest score.

objects were favorable, as shown in Fig. 9 and 10. However, the results should be taken as a simple guide, as the users had to not be exposed to others and wanting to please the researchers could have been a factor in the questionnaire. Nevertheless, we think it is important to report that the participants felt that

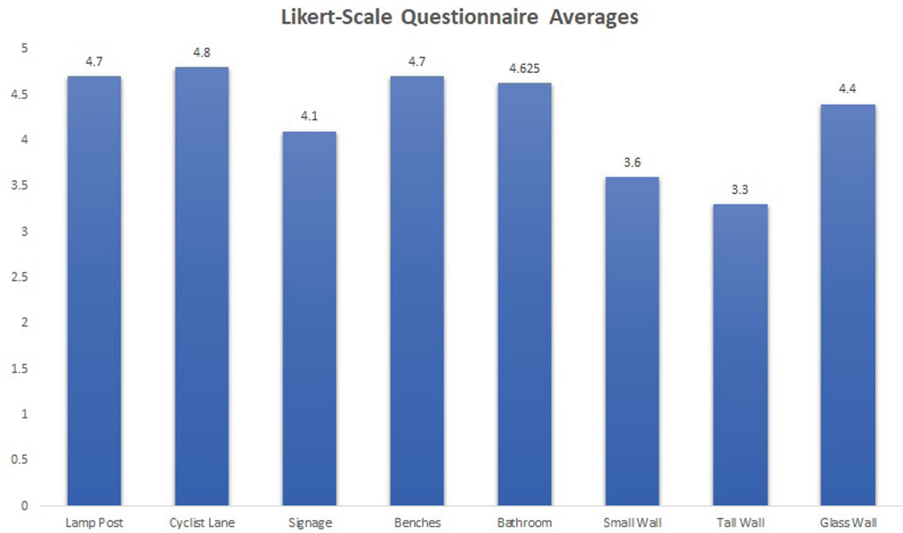

Fig. 10. Likert-Scale Questionnaire about the virtual objects using AR

those objects were well placed for this particular part of the city. Another potential influence on their responses may have been previous exposure to pictures by the city officials. In addition to those questions, they were asked "Are there any other features that you would like to see in place in the "M-path" that would further encourage you to use the space?" and their response was audio-recorded and noted down. For example, one subject mentioned that additional exercise equipment, water fountains, and more trees would benefit the space around them and encourage them more to exercise in it.

5 Discussion

As noted by the data collected from the 10 participants, seen in Fig. 9, it was clear that AR made a difference in their understanding of how the area could look in the near future. Several of the participants had attended previous city meetings where there were talks about the "M-path" and pictures were shown of how it could potentially look like. However, the subjects still had questioned whether themselves or other people in their community would actually use the park as they could not visualize it easily. Informally, we were told by the participants that it was not until they saw and experienced the actual virtual environment while using the HoloLens that they were able to internalize the changes proposed by the city. This response is highly encouraging as it highlights the strength of AR in city planning, allowing citizens to see first-hand what development proposals would look like and how they could impact the environment within the city. As a result, being able to personally experience a virtual design superimposed onto a real location will undoubtedly increase the quality of future designs due to the real-time feedback city planners can receive from citizens.

As for the participants themselves, none of them lost their balance or experienced motion sickness or any other impairment while using the HoloLens. They were all able to walk naturally with the HoloLens on or off, which demonstrates how convenient it is that the headset is hands-free and portable. The HoloLens permits users to wear the headset with glasses on, while VR headsets such as Vive had limited space for glasses.

The participants were amazed that despite the fact that none of them had ever tried on an AR or VR headset, the holograms that they saw around them of the benches, lampposts, and other street furniture, immersed them into a world where the unsafe and isolated park they were familiar with was transformed into a safe, modern, and elderly-friendly park that motivated them to be go outside and be active.

6 Design Implications

After the experiment was completed, we were able to analyze how AR and VR can work outside to re-imagine areas by blending the real and virtual world together to create an immersive and realistic experience for users. Likewise, we were able to examine how AR and VR can make an impact in the architecture, health, and engineering fields. There is an up and coming reality where the construction of a home for a family could take place with a virtual model being shown to them through AR to gauge their response. They could walk through the house in scale and make decisions on each element before any of it has even been constructed. Similarly, city planners and architects will be able to build shopping centers, buildings, and anything that they can think of. In this experiment, we have seen that this is not far from becoming reality with all the recent advancements in AR technology.

Nevertheless, some recommendations on designing these virtual spaces are needed. For instance, the 3D space should be built with bright and light colors if using the current incarnation of the HoloLens as they will appear less transparent when rendering the holograms. Due to the effect of bright sunlight on the headset, it is also recommended that the experiments be done at night or somewhere with adequate shade to also prevent the HoloLens from heating up, which provides for a more immersive experience. Due to the HoloLens' low field of view of 35 degrees in the current version, the use of the Vive VR headset, with its larger field of view of 110 degrees, not only blocked the daylight and made the holograms more visible but it allowed the users to see the entire area without having to move their head or walk around. However, it should still only be used as a supplementary visualization tool to the AR headset as it requires large amounts of external hardware and a battery. However, the upcoming Oculus Go and Oculus Odyssey headsets may address these issues or the Microsoft HoloLens 2 might be enough, which was just recently announced on February, 2019. At the site, we had to use a battery to power the laptop running the VR application, base stations that track hand movements and have to be mounted above head height and the Link Box connecting the Vive to the laptop. Hence, the headset was also connected via cable, unlike the HoloLens which had the advantage of having no external hardware apart from the headset itself. While we understand this is only a technical difficulty which will be eventually addressed with technological development, it points to the importance of the portability of headsets and, in particular, the need to design headsets that can be used in everyday tasks regardless of the environment or time of day. Another important consideration is to try to rely on applications that do not require internet connectivity or at the very least, little connectivity. For example, there may be areas where connectivity is not ideal. In our particular case, we made sure that the Microsoft HoloLens application did not need any internet connectivity, but this may not always be possible in some potential applications.

The implications that this research may have for city planning and health promotion have direct impacts in architecture, construction, and other areas. There are cases, such as the one presented in this work, where constructing different options is either unfeasible or economically counterproductive. We have shown how virtual environments such as those made possible through AR headsets can have an impact in making these decisions easier. AR can make city planning extremely intuitive and integrated with the general public, especially in an area as critical as our elderly and their health.

7 Future Work

From the data collected and the results gathered, there are several next steps that need to be completed. After taking into consideration the participants' requests or concerns for street furniture outside of what they had seen on the AR and VR headsets and their choice of wall, we will share our results with the City of Miami and add the suggested models to the applications to create a final AR environment with the participants' choices included. This design was given to city for consideration of a new "M-Path" to be built in the near future. Ideally, with the cooperation of the City of Miami and others, we are planning to conduct a larger experiment with over 30 participants with the new recommendations. This larger sample size will help to determine if the headsets cause any mobility issues.

8 Conclusion

We conducted a user study to see the feasibility of using AR to enhance city planning and cater to a specific demographic's needs, in this case, the elderly and their health. While it is too early to tell and more research is needed, there are clear indications that this technology can provide a real benefit to accessible city planning and directly improve the health of senior citizens as a result. While the sample size of the experiment was admittedly small, the participants were able to visualize the three possible configurations for the future park, and make a decision based on what they observed. In addition, the participants expressed great satisfaction and enthusiasm with respect to wearing the AR headset and how immersive the experience felt for them. Finally, we have also shown that this technology can be safely used by senior citizens.

The future of accessible city planning can be done with AR, thus fully realizing what the name actually entails. Creating a reality for anyone that augments their current reality. This is an example of an area where AR has a societal impact and can benefit senior citizens on top of the benefits to city planning. We focused on seniors to demonstrate how city planners could accommodate a specific demographic. However, everyone could benefit from AR by directly being able to visualize the future of their cities and living spaces. Families could see their future home before it is built, the elderly could experience their future parks before they are developed and developers could envision future skyscrapers before they dot the skyline. With this technology, cities can cater to the needs of their citizens by being able to see and analyze in advance when planning for smarter, better and more accessible environments.

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