Design of Android Augmented Reality (AR) game called “Public Town Art” and user evaluation of AR impact on human communication

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Design of Android Augmented Reality (AR) game called “Public Town Art” and user evaluation of AR impact on human communication

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Abstract

Humans have gone through a long journey of evolution resulting in continuous improvement of living standards through innovation and creation. But in that journey, one of the factors presenting itself as a constant barrier is social differences. It creates division among the society preventing the creation of an equitable society where every human being gets equal opportunities irrespective of their gender, belief, economical standards etc. This thesis ventures into utilising Augmented Reality (AR) games to evaluate the possibility of improving human communication and reduce social and cultural differences. Public Town Art is the AR game created for this study with simple features which are then evaluated through user questionnaire to analyse the possible influence. Both qualitative and quantitative evaluation is conducted revealing promising results with respect to usability of the game and possible impact of virtual art creation in the area of human communication.

Keywords: Social differences, Augmented Reality(AR) game, evaluation, qualitative, quantitative.
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Apart from this, I am thankful to my father Purnendu Maity, my mother Menoka Maity and elder sister Pritikana Maity who stood beside me and to my friends who supported me in this journey.
Student’s declaration

I, Smritikana Maity, confirm that this dissertation and the work presented in it are my own achievement.

Where I have consulted the published work of others this is always clearly attributed;

Where I have quoted from the work of others the source is always given. With the exception of such quotations this dissertation is entirely my own work;

I have acknowledged all main sources of help;

I have read and understand the penalties associated with Academic Misconduct.

Smritikana Maity
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Chapter 1

Introduction

1.1 Background

Humans are considered one of the most advanced species on this earth. Through constant striving to reach for the unknown and innovate, we have reached a generation where various developments in every aspect of life have uplifted the standard of living. But in this constant journey it is important to focus on the most important part of human life, that is their health. Human health is the condition of complete physical, psychological, and social flourishing, and humans are seen to be the most evolved species on Earth (Brinkel, Khan, and Kraemer 2009). Thus, it is of great importance that in this race of progress, we also make efforts to keep health at the center of attention. In that effort, one of the areas of focus should be social contact as in this fast-moving world, it is the form of communication to express their ideas and feelings. This allows to create an atmosphere of community which can contribute towards creating a safe and sharing world. But in this constant evolution and fast pacing development, the scope of social communication is decreasing day by day. Society is divided into different groups due to social and cultural differences, which operate as a barrier. Asians and Asian Americans, according to recent research on culture and social support, are less likely than European Americans to explicitly seek social assistance for coping with stressful circumstances (Taylor et al. 2004), and they also get less benefits from social support (H. S. Kim et al. 2006). The "cultural distance" concept represents the separation between groups of people or organisation which affects communication resulting in social challenges (Hofstede 1980).

Human ingenuity and creative force are the pillars of human evolution and have provided the pathway for constant innovation. In addition to this the inclination towards collaboration has allowed humans to express their ideas and work towards common goals with greater efficiency. With the advancement of technology, the scope of collaboration and innovative creation
has improved with the use of advanced technology. Now with the help of digital tools and online platforms people all over the world can interact and share their knowledge which has revolutionised the world in every aspect. Technologically enabled social structures are evolving that are altering how people interact and communicate as people use the Internet, networking, and communication technology more and more in their daily lives (Vannoy and Palvia 2010). Research shows that in the face of this change, societal shift is visible as people are depending more on communal support than guidance from authoritative figures like the media, politicians etc. Thus, it might be advantageous to utilise technology to empower people through communication.

Virtual, augmented, and mixed reality technologies have become more and more popular as foundational technology for new ideas during the past few years. Augmented Reality (AR) is fast growing and becoming more popular with the passing moment. The best way to think of AR is superimposing virtual objects into the physical world in real time, creating an interactive environment for its users (Carmigniani et al. 2011). In simpler terms, it is the amalgamation of synthetic and real world (Bujak et al. 2013). It provides for the instantaneous delivery of useful information in the visual spectrum by utilising cutting-edge sensing and imaging technology (Craig 2013). Hevner et al. (2010) defined AR systems supplement the real world with computer generated objects which seem to coexist in the same space as the real world.

It has the potential to elevate all kinds of human senses like touch, hearing and others by enhancing users’ missing senses through sensory replacement like providing auditory cues to help individuals who have vision problems. These experiences, which combine the real and virtual worlds, have captured the interest of many technology enthusiasts in popular culture and are now attracting the attention of academics from fields other than the core technical community, which has historically conducted AR-related research. The amount and variety of AR experiences that are accessible to the general
public have already increased significantly, and as professionals, students, and hobbyists all begin to use these technologies, we can anticipate that trend to continue.

This thesis is focused on employing the urge of human communication to focus on the problem of social differences through utilising modern technology like AR. Applications for mimicking communication can take advantage of AR.

1.2 Rationale

The impact of human connections with respect to both quality and quantity, is evident on mortality risk, health behaviors, and physical and mental well-being. Research shows human communication is essential and has a positive impact on human health. Starting from early childhood, its impact can be seen throughout life showing its sign on human health (Gilligan, Suitor, and Pillemer 2015). Various reasons are responsible for the diminished communication which ranges from cultural differences to overuse of technology, resulting in an increase of health risks through mental health issues, cardiovascular diseases etc.

Numerous sectors, including healthcare, education, and others have made extensive use of AR. Here, we wish to investigate the potential for its use in social interaction. Games have the ability to transcend cultural barriers, and co-creation projects might promote racial harmony. The goal of this research is to develop a game based on AR and assess user evaluation and opinion about its possible impact on fostering interactions between individuals - young and elderly, people from various origins, beliefs and cultures, etc.

1.3 Scope

The effective utilisation of AR to connect people needs the assessment of opinion of the users about their interests in virtual environments. However, for the purposes of this study, we believe that those criteria have been satisfied. The platform for development is determined to be the video game engine Unity. Here, our main goal is to create a single player game to demonstrate simple tasks in real world, arrange already existing things in a common physical space and understand user impact and their opinion. Users will be able to play the game in real time, and the item sizes are kept uniform.
1.4 Research aim and objectives

This study is targeted towards the impact of using new age technologies like AR to gather user evaluation on impact of it on human communication, especially social interaction to eradicate the social differences with the below mentioned Research Objectives (RO) and Research Questions (RQ).

- RQ1. What is the impact of AR on humans in various industries and how can communication through gaming influence society?
  - RO1: Carry out literature review on usage of Augmented Reality.

- RQ2. What is the users’ experience using the Public Town Art application in terms of usability?
  - RO2: Develop an application in Unity for observing the creation of virtual assets.
  - RO3: Conduct user evaluation of the created application to gather user feedback.

- RQ3. What are users’ opinions regarding the contribution of AR games towards human communication?
  - RO4: Investigate and reflect upon usability and sustainability aspects of the application using user feedback.

1.5 Contribution to research

This study aims to explore the utilisation of AR for benefits of interaction by creating an android game. This will provide the future scope of virtual interaction among strangers that can help to develop social relations and reduce cultural differences. The game is developed on the Unity platform.

1.6 Organisation of the thesis

This section will give an overview of the structure of this report.

Chapter 1 gives the scope of the research.
Chapter 2 provides a literature review of this study.
Chapter 3 explains the methodology chosen for this study.
Chapter 4 shows the design of the solution.
Chapter 5 and 6 focus on the result and its discussion.
Chapter 7 and 8 present a conclusion and limitations based on the results.
Chapter 2

Literature Review

In this section, the focus will be on the impact of technologies like Augmented Reality and Mixed Reality (MR) on society and also on ongoing work like AR and MR integrated applications as that will help to answer Research Question 1 through secondary data.

2.1 Augmented Reality and Mixed Reality

Immersive 3D environments have received a lot of attention from researchers in a variety of scientific fields, including display technology and human-computer interaction. By leveraging AR and MR, innovative solutions can be created prioritising engaging user experience along with playing a significant role in contributing to the creation of a more equitable society.

Linaza, Gutierrez, and Garcia (2013) conducted a study using AR games in the field of tourism, where they provided the users with historical knowledge about Spain’s Urgull Mountain and encouraged exploring nature. The promising result of this study shows that AR can be employed to attract users to increase awareness. The work of Bonetti et al. (2019) showed the integration of AR techniques within a physical store to enhance the experience of customers in retail space. The findings of qualitative analysis showed improved brand engagement and customer satisfaction. The results presented in this work indicate that increasing motivation using AR games is possible, which is promising for an AR game like “Public Town Art” which aims to motivate people to communicate with strangers and thereby promote inclusion.

Chang et al. (2013) proposed a dynamic fitting room system using Microsoft Kinect and Augmented Reality Technology which had the capability to detect users’ clothing sizes and enabled them to interact with the selected garments. This allowed customers to virtually try on clothes and make more informed decisions, leading to increased satisfaction and reduced inconvenience of size alterations within the store. This further supports that AR has
the capability to captivate users by providing satisfaction of use. Furthermore, AR has found applications in the healthcare, education, and tourism industries, among others, enabling new ways of learning etc. In a study conducted by Wang et al. (2014), the researchers examined and compared students’ engagement in collaborative inquiry learning using an augmented reality (AR) simulation system and a traditional 2D simulation system. According to the results, pupils responded more favorably to the AR-based approach than the conventional method during the inquiry phase which indicates its potential for increased engagement.

Figure 2: Implementation of (a) quiz, (b) puzzle and (c) AR by Linaza, Gutierrez, and Garcia (2013)

Akçayır et al. (2016) examined the application of AR in science laboratories to assess its impact on university students’ laboratory skills. The findings demonstrated that the use of AR not only enhanced students’ capability to learn science but also had a positive effect on their attitudes by increasing motivation towards their tasks. In the work by Kamarainen et al. (2013), AR was combined with probe technology and utilised to support field trips in an environmental education course. Through teacher interviews and student surveys conducted during the study, it was discovered that this integration increased student engagement and facilitated the establishment of connections between their learning and new real-life situations.
Pan et al. (2006), explored the use of virtual learning environments (VLEs) in the field of education. They provided evidence that VLE can be a resourceful tool to spread knowledge in a wide range of situations, even when the traditional methods have presented challenges. The work done by Liu et al. (2007) proposed an MR classroom designed for a neighborhood primary school in Singapore. In the MR classroom, two modules on the solar system and the plant system had been built, supporting both classroom instruction and self-learning. This provided promising results in student participation. Lee et al. (2019), provided an example application and user research built around a tabletop gaming experience between a real and a virtual person, as well as a technological method to realising physical-virtual interactivity in AR in the context of a tabletop setting. In another work of Mahmood et al. (2019), they proposed a system for remote teamwork that uses MR to analyse geospatial data. Their method offers immersive visualisation along with a number of crucial collaborative engagement and analysis features and provided evidence of increased efficacy of remote cooperation. Hall et al. (2001) described a method for utilising hybrid reality technology to improve users’ interactions and knowledge of historical artifacts and their connections to them.
2.2 Communication through gaming

Games that aid in establishing social bond between players, as opposed to games played in isolation at some form of competition, or games played for money, are referred to as social games. The attempt to utilize the positive impact of gaming in day to day life to improve human world is already on the way. Games have the potential to connect people and improve human relations through collaboration. This gives a scope for humans to connect with people along with improving cognitive functions. With the advancement of technology, it is also essential to include these benefits for interactions and cultural unity.

The work proposed by Metaxas et al. (2005) discussed the development of a mixed reality game for three to four youngsters between the ages of 11 and 14. It was meant to encourage and facilitate interaction between players both during and after play. The work of Decortis and Rizzo (2002) used a user-centered design process to create a play environment that takes advantage of the child’s physical surroundings and sensory modalities. Khoo et al. (2008) proposed a social-physical interactive family video game, created especially for enjoyable game play between the young and the old. This provides a solution for parents staying away from their children, allowing
them to virtually interact and play games in real-time.

Figure 5: Environment setup for implementation by Marichal et al. (2017)

Marichal et al. (2017) proposed a solution for imparting mathematical education to school age children through tablets. They took into account significant cognitive ideas in the conception of interaction, such as cognitive offloading, conceptual metaphors, and epistemic acts. Brederode et al. (2005) proposed a gaming solution that stimulates social connections while playing and to bring together kids with and without physical or learning disabilities. It took into account the various needs of different groups of target audience and helped to form a bridge between the challenges with the existing solutions. Kors et al. (2016) proposed a multisensory mixed reality game that offers a first-person account of a refugee’s journey.
Chapter 3

Methodology

3.1 Research Design

DSR (Design Science Research) methodology is a popular approach in the field of information systems and computer science research. It focuses on creation and evaluation of Information Technology (IT) artifacts to contribute towards solving identified problems in particular domain (Hevner et al. 2010). These artifacts can be models, methods or any kind of practical application of modern systems to address real world issues. Design science-based research can be carried out in both an academic setting and in an organisational context (Dresch et al. 2015).

![Methodology by Peffers et al. (2007)](image)

Figure 6: Methodology by Peffers et al. (2007)
According to Peffers et al. (2007), DSR consists of 6 major steps which includes identification of problem area, defining objectives, designing artifact to solve the problem and demonstration and rigorous evaluation of said artifact and finally communicating the problem and its relevance to appropriate audiences.

This research adopted a modified version of DSR with focus in identifying objectives in problem domain, design, demonstration and evaluation of the artifact.

As per Johannesson and Perjons (2014), the first step in DSR is to identify challenges, inefficiencies, or limitations in existing practices. In this study, the aim is to design an AR game to understand and evaluate its impact on the issue of social differences.

The development of the artifact denotes the creation of the AR game using Unity platform with 3 different stages (Create, Move and Destroy). Demonstration phase was conducted using an illustrative method which denoted its practicality and was expressed through proof of concept. The game was demonstrated to end users through meeting and face to face training so that the participants were equipped with the required skills to operate the game.

![Figure 7: Methodology by Johannesson and Perjons (2014)](image)

Evaluation conducted here is a mixture of qualitative and quantitative approach as it gives a deeper, more thorough insight of the impact, usefulness, and efficacy of the artifact. The goal of qualitative assessment is to obtain
rich, in-depth insights into the usability, utility, and effect of the artifact by concentrating on understanding the users’ views and interpretation of it. It is achieved through interviews and open-ended surveys questions. On the other hand, the goal of quantitative assessment is to give objective and quantifiable proof of the efficiency, and impact of the artifact. It is achieved through the systematic data collection and its statistical analysis through questionnaires with closed-ended questions in the questionnaires which in turn is utilised to evaluate and quantify various elements of the artifact’s performance and influence.

3.2 Participants

The participants involved in the evaluation phase consisted of both university students and skilled professionals. The sample group included 44 people from various regions of the world like Sweden, India, Germany etc. to provide representativeness from various ethnic backgrounds matching the objective of this study. All the users reply to the questionnaire anonymously. The age group lies between 20 to 42 years old. Although this sample group consists of diverse users, there is selection bias with respect to education and experience. This is because all of the users are highly educated (university level) and belong to a small age group. But focus here is given mainly on the usability, impact and ideas which are gathered through the questionnaire in the evaluation phase.

3.3 Data Collection and Analysis

Following the design research methodology, the evaluation phase consisted of semi-structured interviews, and questionnaires.

The usage of semi-structured interviews allows the generation of comparable data from all participants yet provides the scope for flexibility (Hol- loway and Galvin 2016). It allows to understand user opinion on topics like their day to day activity, current usage of games and phones, usability of created game and possible impact of AR in social issues.

The first step included sharing the APK file (Android Package Kit) through Google Drive to all the participating users. This can be used to install the game in the users’ android phone and then they can play in their own space using just their mobile device. They were briefly explained about the study and given a quick guide of game. The questionnaire used consists of 3 sections. The first section contains general questions regarding the user of the game which is filled before playing it. Then the user is given access to the
game and all details are provided for smooth operation of the game. The second section focuses on the usability of the game. The third section consists of questions, ideas and impact of the game. Both these are to be filled after playing the game. The entire process was executed through the combination of direct contact, video calls and self-administered questionnaires. The close-ended questions used 7-point Likert scale.

Google Forms was used to store and process the questionnaire response and descriptive statistical values like mean and standard deviation and inferential statistical analysis techniques like chi-square test of independence and pearson correlation were used to fulfill quantitative data analysis through coding in Google Colab.

Descriptive statistical analysis is used to understand the existing characteristics or features of the available data whereas Inferential statistical analysis is used to make generalization about a population using a sample dataset.

Mean of a sample data is calculated by the sum of all the values divided by the number of values in the dataset. It is expressed in Equation 1.

\[
A = \frac{1}{n} \sum_{i=0}^{n} a_i
\]  

where \( A \) denotes arithmetic mean, \( n \) denotes number of values, \( a_i \) denotes data values.

Standard Deviation helps to assess the degree of dispersion of the available dataset from the mean of the data which can be expresses using the formula in Equation 2.

\[
\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}}
\]  

where \( \sigma \) denotes standard deviation, \( N \) denotes population size, \( x_i \) denotes data values, \( \mu \) denotes mean.

Chi-Square test of independence is used to determine the existence of any relation between two categorical datatype and is calculated using the formula in Equation 3.

\[
\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}
\]  

where \( \chi^2 \) denotes chi square value, \( O_i \) denotes observed value, \( E_i \) denotes expected values.
Pearson Correlation is used to determine the relationship between two variables. There are three main kinds of correlation:

1. Positive: If the value is between 0 and 1, there is positive correlation which means with increase in one variable the other also increases and vice versa.

2. Zero: If the value is zero, then there is no correlation.

3. Negative: If the value is between -1 and 0, then there is negative correlation which means with decrease in one variable, the other increases and vice versa.

It is calculated using the formula given in Equation 4.

$$ r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} $$  \hspace{1cm} (4)

where $r$ denotes correlation coefficient, $x_i$ denotes value of $x$ variable, $\bar{x}$ denotes mean of $x$ variable, $y_i$ denotes value of $y$ variable and $\bar{y}$ denotes mean of $y$ variable.
Chapter 4

Implementation of “Public Town Art” game

The design aim of this game is to seamlessly integrate the physical world and virtual world created by the user, enabling them to interact freely within an augmented space.

4.1 Platform Selection

The first step towards this game creation is the selection of game engines to be used in this process. Game engine is the software environment used for developing the games which consists of customised settings and configurations available readily to simplify the development process through a range of programming languages. Unity is chosen in this case as it is the most popular choice of game engine as it enables rapid prototyping and high-quality customisation rendering technology. It allows developers to create both interactive 3D and 2D games with its feature rich fully integrated development engine (S. L. Kim et al. [2014]). Moreover, it provides cross platform build (PC, Android, iOS etc.) with both free and paid toolset which makes implementation easier. It has made AR and VR game development easier as Unity supports it through available packages (Schardon [2023]).

For game execution, Android mobile device is selected as the platform where the created game is deployed and users get the chance to play it. The user evaluation is stored in Google Form and analysed using Google Colab.

4.2 Concept of the Game

The game design revolves around creating virtual objects in the physical world viewed through the camera of the mobile device. It has three different functions: Create, Move and Destroy.
Create: Here the user will have a scrollable list of virtual objects to choose from, which will be created in the physical space using the mobile device camera. The output from the camera will also show the target location on which the virtual object will be created on clicking to enable correct placement of the objects in the physical world. If the chosen position already contains a previously created virtual object it will place the new object on top of the existing one relative to the chosen location.

Move: Here the user can move the already created virtual objects to a different location using the same indicator view as the create phase.

Destroy: Here the user can destroy the virtual object from the shared space. If the object selected for destroying has other objects above it, they will be moved down to the plane.

4.3 Game Architecture and Design

The operating system chosen for implementation is Android. Google’s AR-Core is an Android development kit specifically designed for augmented reality creation. It offers a range of features like motion tracking, environmental understanding and light estimation, which facilitate integration of virtual content into the real world (Lu et al., 2021).
The development of the different phases of the game is conducted using custom code using various available packages and features of Unity and ARCore. The testing of the developed artifact was conducted in an android mobile device (Xiaomi POCO F1 model) and went through the process of
meticulous refinement to achieve the final version.

It consists of two Scenes: Home and Indicator Scene. The Home Screen of the application welcomes the user with the option of playing or quitting the game utilizing the “Home” Scene.

On the Play option, “Indicator” Scene is executed and all the functions are integrated there. The camera of the device is opened and it gives the user the option of three functions - Create, Move and Destroy.

In all the functions of the game designed, the location of the click is very crucial. In order to keep a homogenous approach through the phases, the target location is always shown through an indicator on the screen which is also a virtual object of the game. This helps to visualise the actual location which will be used in the game when viewing the world through the mobile camera. The indicator will be shown with respect to any detected surface in the physical world which is achieved through the available property of Unity3D called Raycast. Here we are using only trackable planes through Raycast and using Indicator with respect to these detected planes to have
a seamless experience. The indicator will be updated continuously with all kinds of movement of the mobile and has been configured to be viewed only on the center of the mobile screen.

Figure 11: Indicator view in the game (yellow arrow)

4.3.1 Create phase

In this phase, user gets a scrollable list to choose the item they want to create in the camera view area called GameObject. The indicator shows the target location in the scope of view of the camera.

If the user touches the screen of the device, it will find the actual location of the indicator in the physical world on the detected plane and instantiate the selected GameObject in that location using anchors. An Anchor is a unique component that overrides the location and orientation of the Transform component of the GameObject and locks them in place in the actual world. This helps to keep the GameObject in its position without any drift, which might occur due to the movement of the mobile device.
CHAPTER 4. IMPLEMENTATION OF “PUBLIC TOWN ART” GAME

(a) Create without collision

(b) Create with collision

Figure 12: Create function without and with collision

Before placing the object, it will check whether the area of the GameObject collides with an existing GameObject. In case of collision, it will calculate the maximum bound of the existing object and place the new one on top of that keeping the orientation and other location parameters intact. This is possible as the GameObject has a Collider component which is in the same dimension as the object and is essential for collision detection. This allows relative positioning of the objects in case of collision.

4.3.2 Move Phase

This phase will allow users to move the existing objects from one place to another.
Firstly, if a touch is recognised it will get the location of the Indicator and check if any GameObject is present utilising the RigidBody component. If an object is found it will turn its color to green to indicate its selection for movement. Then the user can move the camera and choose a new location using another touch on screen and the object will be moved from old location to new one and its color will be reverted to its original one.

### 4.3.3 Destroy Phase

This phase will allow users to destroy any existing GameObject. If user touches the screen, the Indicator location will be used to check if any GameObject is present in that location.
The RigidBody component of the GameObject is utilised to detect the presence in the selected position and on detection it is destroyed from the view. Before destroying, it checks if the object has any other objects above it. If they are found, after destroying the objects above are moved down on the plane.
Chapter 5

Results

To achieve RQ3, qualitative and quantitative assessment of the created game is conducted. The results are shown and various features are discussed in detail.

The user feedback gathered at the end of the demonstration phase is utilised in this section to reflect upon the kind of response of users and their views regarding social impact of the AR games on human communication. The feedback has three different sections. Pre-game section has some general questions regarding the users and their day-to-day activities, the usability section is dedicated to the functions and ease of use of the application created and finally the post-game section is dedicated to document the users’ opinion about various ideas and topics.

5.1 Quantitative Analysis

In this section the 7-point Likert scale is used to analyse the response of various kinds of questions discussed below. Here the scale is defined by assigning 7 to strongly agree and 1 to strongly disagree.

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<th>Value</th>
<th>Meaning</th>
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<td>1</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>2</td>
<td>Disagree</td>
</tr>
<tr>
<td>3</td>
<td>Somewhat Disagree</td>
</tr>
<tr>
<td>4</td>
<td>Neutral</td>
</tr>
<tr>
<td>5</td>
<td>Somewhat Agree</td>
</tr>
<tr>
<td>6</td>
<td>Agree</td>
</tr>
<tr>
<td>7</td>
<td>Strongly Agree</td>
</tr>
</tbody>
</table>
These responses are utilised for statistical analysis to understand the basic features of the data and inspect any relation between the variables captured. The scale and its assigned meaning are defined below. These values are referenced throughout the analysis.

Before analysing the data, first the required columns of the data are converted into categorical value. The datatypes of all the columns are shown in Figure 15.

The age of the users ranges between the age of 20 to 42 with average density appearing around the age of 25 to 32 which is depicted in the boxplot shown in Figure 16 with respect to gender.

```
time          object
pre_age       int64
pre_gender    int64
pre_smartphone_use int64
pre_use_game  int64
pre_time_game object
pre_ar_use    int64
pre_discrimination int64
pre_isolation int64
pre_differences_to_interaction int64
pre_social_time int64
pre_activity_type object
pre_technology_connect int64
pre_technology_connect_background int64
game_ideal_use object
game_ui       int64
game_integration int64
game_function int64
game_learn    object
game_create   int64
game_move     int64
game_destroy int64
game_recommend int64
game_experience object
post_barriers_presence int64
post_barrier_details object
post_create_art int64
post_create_virtualart int64
post_create_collab_interact int64
post_create_collab_include int64
post_feature_add object
post_marble_race int64
post_minecraft int64
post_create_interact_include int64
post_ideas     object
post_belonging int64
```

Figure 15: Datatype of collected data
CHAPTER 5. RESULTS

Figure 16: Boxplot of age with respect to gender

To understand the average amount of time users spend in playing games, histogram with respect to gender and time spent is shown in Figure 17. It is evident that most of the users spend 0-1 hours everyday playing some kind of games which means games can be utilised to have a positive impact on users. Among all the collected data, around 47.7 percentage of users have used AR games which signifies that AR games are quite popular among young generations which is shown in Figure 18.

Figure 17: Histogram of time spent in games
According to Figure 19, it is evident that the use of smartphones and games is very popular as most of the users have strongly agreed with the statements.

Table 2 shows the result of pre-game section. It is evident that most of the users somewhat agree that they feel isolated in their day today life (mean=4.681, standard deviation=1.394) and most of them somewhat agree that social differences can be a barrier to interactions (mean=5.181, standard deviation=1.262).
Pearson correlation is conducted which helps to discover relationship between assigned numerical values for different pre-game questions and results are shown in heatmap form. It can be seen that age has a negative correlation with the evaluation of multiple correlation like AR usage, smartphone usage, technology usage for connection etc. This means that with increasing age the sample data showed decreased value for the given parameters.

We can also see positive correlation among few parameters like technology used for connection and people choosing social activities. This defines that within the sample data, people who prefers to engage in social activities also prefers to connect with people using technology. The detailed Pearson correlation heatmap is shown in Figure 20.

Table 2: Mean and Standard deviation of Pre-Game Questionnaire.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I use smartphone frequently.</td>
<td>5.613</td>
<td>1.481</td>
</tr>
<tr>
<td>I often play mobile games.</td>
<td>5.318</td>
<td>1.610</td>
</tr>
<tr>
<td>I have experienced discrimination or prejudice based on my race, ethnicity,</td>
<td>4.909</td>
<td>1.394</td>
</tr>
<tr>
<td>gender, sexuality, religion, or any other aspect of my identity.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I have felt socially isolated or disconnected from others.</td>
<td>4.681</td>
<td>1.521</td>
</tr>
<tr>
<td>I believe that social differences can be a barrier to social interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and community building.</td>
<td>5.181</td>
<td>1.262</td>
</tr>
<tr>
<td>I often engage in social activities with friends or family members.</td>
<td>5.340</td>
<td>1.429</td>
</tr>
<tr>
<td>I have used technology to meet new people or connect with others.</td>
<td>5.500</td>
<td>1.438</td>
</tr>
<tr>
<td>I have used technology to connect with people from different backgrounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>or communities.</td>
<td>5.386</td>
<td>1.466</td>
</tr>
</tbody>
</table>

Using Chi-Square test of independence, we can observe the existence of any relation between gender and AR use among users.

**Null hypothesis:** There is dependency between gender and AR use.  
**Alternate hypothesis:** There is no dependency between gender and AR use.
The Chi Square value is: 14.547978080120938
The p value is: 0.005736693404073713
The null hypothesis can be rejected

The alpha is 2 percentage or 0.02 as the confidence level is considered 98 percentage or 0.98. The p value obtained in the experiment is less than alpha, so the null hypothesis can be rejected. Thus, it provides evidence that there is no dependency between gender and AR use.

![Heatmap of Correlation for Pre-Game Questionnaire](image)

**Table 3** shows the mean and standard deviation values regarding the design and ease of use of the game created which ranges between 6 or higher which signifies response falls under agree and strongly agree section. Most of the functions were basic and users were easily able to learn and execute the targeted task with simple instructions. The mean value of 5.75 for recommendation depicts that most of the users agree that they will engage in this game.
### Table 3: Mean and Standard Deviation of Usability questionnaire

<table>
<thead>
<tr>
<th>Statement</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>The User Interface (UI) is easy to use</td>
<td>6.113</td>
<td>1.104</td>
</tr>
<tr>
<td>I found that the various functions in this system were well integrated</td>
<td>6.090</td>
<td>1.074</td>
</tr>
<tr>
<td>It was easy to understand what the functions do</td>
<td>6.250</td>
<td>1.059</td>
</tr>
<tr>
<td>I was able to create objects easily</td>
<td>6.454</td>
<td>0.998</td>
</tr>
<tr>
<td>I was able to move objects easily</td>
<td>6.250</td>
<td>1.037</td>
</tr>
<tr>
<td>I was able to destroy objects easily</td>
<td>6.340</td>
<td>1.033</td>
</tr>
<tr>
<td>I would recommend this game to others</td>
<td>5.750</td>
<td>1.203</td>
</tr>
</tbody>
</table>

In the post-game section, the opinions of users were collected about use of virtual art and its impact which is plotted in the histogram in [21].

![Figure 21: Trend of User Opinion for various art creation for social cause](image)

It is evident that most of the users strongly agree that creating virtual art through collaboration can be useful to increase interaction and reduce social differences.
Table 4: Mean and Standard Deviation of Post-Game questionnaire

<table>
<thead>
<tr>
<th>Statement</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creating art is a suitable activity to engage people from different backgrounds or communities to collaborate</td>
<td>6.022</td>
<td>1.130</td>
</tr>
<tr>
<td>Creating virtual art using an augmented reality application in a mobile device is a suitable activity to engage people from different backgrounds or communities to collaborate</td>
<td>5.954</td>
<td>1.160</td>
</tr>
<tr>
<td>Collaborative creation of virtual art using AR encourages social interaction with others do</td>
<td>5.954</td>
<td>1.119</td>
</tr>
<tr>
<td>Collaborative creation of virtual art using AR promotes social inclusion and reduces social differences</td>
<td>5.818</td>
<td>1.206</td>
</tr>
<tr>
<td>Building marble racetracks and racing together would encourage social interaction with people from different backgrounds or communities</td>
<td>5.295</td>
<td>1.132</td>
</tr>
<tr>
<td>Building minecraft style creations together would encourage social interaction with people from different backgrounds or communities</td>
<td>6.045</td>
<td>1.098</td>
</tr>
<tr>
<td>Creating realistic virtual art together would encourage social interaction with people from different background or communities</td>
<td>5.977</td>
<td>1.151</td>
</tr>
<tr>
<td>It is important to feel a sense of belonging and inclusion in our social interactions in this world</td>
<td>5.931</td>
<td>1.128</td>
</tr>
</tbody>
</table>

Table 4 shows the mean and standard deviation of the various opinions of the users regarding use of games for social causes. The mean value of 5.931 for the question of need of social belonging depicts that most users agree on the issue of social inclusion and mean value of most of the questions about various ideas of virtual art and collaboration were near 6 which means most of the users agree in the statements.

Using Chi-Square test of independence, we can observe the existence of any relation between gender and opinion about presence of barrier.

**Null hypothesis:** There is dependency between gender and presence of barrier.
**Alternate hypothesis:** There is no dependency between gender and presence of barrier.

- The Chi Square value is: 4.860907610907613
- The p value is: 0.08799689005136553
- The null hypothesis is accepted

The alpha is 2 percentage or 0.02 as the confidence level is considered 98 percentage or 0.98. The p value obtained in the experiment is less than alpha, so the null hypothesis can be accepted. Thus, it provides evidence that there is dependency between gender and presence of barrier.

### 5.2 Qualitative Analysis

In the user feedback, along with quantitative responses, multiple open-ended questions were presented in all the sections mentioned earlier to allow the users to express their opinions and suggestions to various questions discussed below. This allows to add depth to the analysis and understand problems from various aspects and provides ground for future development or improvement.

**What types of social activities do you enjoy doing with others? (e.g., playing sports, going to the movies, having dinner parties, etc.)**

This question was targeted to understand the kind of activities people like to engage in which can help to produce games revolving that activity which will allow more user interest. The user’s responses varied extensively, including various activities involving social engagement.

**What was your overall experience about the game?**

Most of the users were positive about the experience of the game and provided positive feedback and few suggestions were also added to improve the experience.

"The game was easy to play and users are free to build whatever structure they like, maybe adding different kind of objects will help improve the game and make it more interesting"

"I find it fun and it open rooms for the players to be creative to build different structures using the boxes"
“The game was super easy to learn and it provide a good opportunity to interact with others”

“The UI needs to improve. So do the functions in the game.”

What are the barriers that prevent you from interacting, or makes it difficult for me to interact with people from different backgrounds or communities?

In this section users expressed which kind of issues they face in the real world to initiate communication. This helps to understand individual opinions about their struggles.

“How introvert its difficult to initiate communication with others”

“- Lack of self confidence
- Sometimes the other person doesn’t seems approachable.”

What features, if any, would you like to see in an AR game designed to increase social interaction? (e.g., particular game ideas, features etc.)

This question helped to understand various other features user would like to make this game more popular which ranges from adding more features to animations and sound effects to improve user experience.

“- Good sfx (effects for sound) - multiplayer interaction - Some decent animations while creating, moving, destroying those objects.”

“More interactive features with ability to move objects smoothly.”

Do you have any ideas about other popular games which you feel will be interesting to play with other people using AR?

This question opens the door to future possibilities of various game ideas which can help to improve social interactions.

Angry Birds AR: Isle of Pigs, Virtual board games, Multiplayer shooting games, Car racing games etc.
Chapter 6

Discussion

This study presents the design and evaluation of an AR game called Public Town Art and user opinion on its impact in human communication. The results of evaluation of the game helps understand and reflect upon the importance of AR games in the problem area of social differences and helps to answer RQ1, RQ2 and RQ3.

**RQ1.** What is the impact of AR on humans in various industries and how can communication through gaming influence society?

The important works in the field of AR were discussed in the literature review section which helps to answer this question through secondary data. The works discussed helps to establish that AR is an important tool which has been used by multiple researchers providing evidence that games revolving around AR and MR have proven to be efficient solutions to increase user motivation and engagement. Thus, if used with structured ideas this can be a promising venture to apply its positive impacts towards social causes like creating equitable society by increasing communication.

**RQ2.** What is the users’ experience using the Public Town Art application in terms of usability?

The qualitative and quantitative evaluation done in this study helps to answer the following question. Users’ responses regarding various aspects of the game like UI, various functions integrated, ease of use etc. were mostly positive. Users, although suggesting few points of improvement to make it more engaging, were satisfied with the overall experience of the game. Through user data, it is clear that they were entertained and engaged in the game and were ready to interact with the game again.
**RQ3.** What are users’ opinions regarding the contribution of AR games towards social communication?

The data collected through three sections of questionnaire was evaluated thoroughly to understand users’ day-to-day experience, ideas and opinion regarding the issue of social differences. It was found that on average most of the users have faced discrimination at some point of time. It was evident through the data collected that all the users actively participate in playing games and are equipped to use smartphones in their daily life. Thus, the idea of creating mobile games to target the issue of social difference was proven to be promising. Moreover, most of the users strongly agree that the concept of collaborative virtual art creation is engaging and can have positive results in increasing social interaction.
Chapter 7

Conclusion

The use of augmented reality is growing across a number of industries, including manufacturing, Information Technology (IT), education etc. Its impact on human life has made it possible to acknowledge its importance and embrace it rapidly in today’s world. This study sought to investigate the usage of augmented reality (AR) games for human interactions. The goal was to create an AR game that would help players comprehend technology’s influence and its impact on human communication. The game would be able to instantaneously provide a platform to initiate interactions. It would allow to create a bridge of communication irrespective of social beliefs, ethnicity or any other social barriers. The analysis done in the evaluation phase helped to further reveal that in day-to-day life people face some kind of discrimination based on their belief, status, ethnicity, background etc. Additionally, the younger generation is adept at using smartphones for various activities, including playing games. In light of this, using mobile games for this reason is a viable strategy. Moreover, the game received positive response from its users because of its simplicity and utilisation of a new growing technology like AR. It was evident that users strongly agree on the possibility of utilising virtual art games for reducing social differences and discrimination which can help to create a more positive and inclusive future.
Chapter 8

Limitations and Future Works

The evaluation from the user feedback provided valuable insights into the user perceptions and ideas about the use of AR games towards reducing social and cultural differences by fostering increased human communication. The evaluation predominantly highlighted the positive impact and potential in the regard of the usability of the game and real-life impact based on user experiences. However, there are limitations with respect to the scope of the game development and participant group who were part of the evaluation phase.

The game created is a single player game and all the feedback collected is based on the individual user perception. The possibility of creating this game for multiplayers and using cloud solutions for real time data distribution and interaction will help to further improve the experience and understand its practical value. In single player mode the participants were satisfied with the experience and the simple functions included in the game. However, it was shown through qualitative research that adding more features and audiovisual effects will further enhance user experience, boost engagement thus making the game more effective.

With respect to the participant group, the focus of this study was to assess the impact of the game by including individuals with diverse cultural backgrounds. Therefore, a total of 44 people from Sweden, India and Germany were included. However, it is important to note that it involves selection bias as all the users are highly educated with a skilled background. While this approach provided valuable insights into the intended effects, future studies should aim to include a larger and more diverse participant pool to enhance analysis and gather additional inputs based on a wider range of user experiences and impressions.


Khoo, Eng Tat et al. (2008). “Age invaders: social and physical inter-generational mixed reality family entertainment”. In: Virtual Reality 12, pp. 3–16.


Schardon, Lindsay (May 2023). *What is unity? – A guide for one of the top game engines*. URL: https://gamedevacademy.org/what-is-unity/.


Appendix

Code Snippets of Game Implementation

```csharp
void update()
{
    updatePlacementPose();
    updatePlacementIndicator();

    if (placementPoseIsValid && Input.touchCount > 0 && Input.GetTouch(0).phase == TouchPhase.Began)
    {
        if (EventSystem.current.IsPointerOverGameObject(Input.GetTouch(0).fingerId))
        {
            if (checkStage == 1)
            {
                Debug.Log("Success: before place object");
                PlaceObject();
            }
            else if (checkStage == 2)
            {
                Debug.Log("Success: before destroy object");
                DestroyObject();
            }
            else if (checkStage == 3 && isObjectSelected)
            {
                Debug.Log("Success: before move object highlight");
                MoveObject_highlight();
            }
            else if (checkStage == 3 && isObjectSelected)
            {
                Debug.Log("Success: before move object shift");
                MoveObject_shift();
            }
        }
    }
}
```

```csharp
private void PlaceObject()
{
    // Checking if mouse position already has any objects placed
    bool overlap_found = false;
    originalPose = placementPose;
    // Execute overlapping check and continue running it if overlap occurs
    do{
        overlap_found = CheckOverlap();
    }while(overlap_found);

    // Instantiate only if position found with no collision and attach anchor for stability
    ARAnchor anchor;

    var instantiatedObject = Instantiate(objectToPlace, placementPose.position, placementPose.rotation);
    if ((instantiatedObject.TryGetComponent<ARAnchor>(out anchor))
    {
        anchor = instantiatedObject.AddComponent<ARAnchor>();
    }

    Debug.Log("Success: Created regular anchor (Id: [anchor.nativePtr]) and placed object.");
}
```
```csharp
public bool CheckOverlap()
{
    //Calculating overlap area from parent entity object
    Collider[] hitColliders = Physics.Overlap(new Vector3(elementPose.position, objectToPlace.transform.localScale / 20);
    Debug.Log($"Success: object size is {objectToPlace.transform.localScale}.");
    positionAbove = placementPose.position;
    bool overlap = false;
    foreach (Collider col in hitColliders)
    {
        Debug.Log($"Success: tag of collider is {col.gameObject.tag}.");
        if (col.gameObject.CompareTag("object") && positionMax == col.bounds.max)
        {
            overlap = true;
            //Calculating the top position for overlapping condition
            positionMax = col.bounds.max;
            //Create the position in y-axis with maximum value of colliding object
            positionAbove.y = positionMax.y;
            Debug.Log($"Success: overlap at (placementPose.position) mouse position and object location is (col.transform.position) and placementPose.position={positionAbove}.
            
            //2021-03-22 13:53:27:15.228 14492 14534 Info Unity Success: overlap at (8.23, -1.26, 6.22) mouse position and object location
        }
    }
    return overlap;
}

public void MoveObject_Hilight()
{
    Debug.Log($"Success: Inside Move Highlight function");
    Ray ray = Camera.main.ScreenPointToRay(Input.mousePosition);
    RaycastHit hit;
    if (Physics.Raycast(ray, out hit))
    {
        if (hit.collider.gameObject.CompareTag("Cube1"))
        {
            //Debug.Log($"Success: Inside Color change object if condition");
            //objectRenderer = hit.collider.GetComponent<Renderer>();
            //objectRenderer.material.color = Color.green;
            isObjectSelected = true;
            Debug.Log($"Success: Inside if, original getting position");
            //hitObjecTransform = hit.collider.GetComponent<Transform>();
            selectedObject = hit.collider;
            originalColor = selectedObject.GetComponent<Renderer>().material.color;
            selectedObject.GetComponent<Renderer>().material.color = Color.green;
        }
        else
        {
            Debug.Log($"Success: Inside Color change object else condition");
            //renderer.material.color = _originalColor;
        }
    }
}
```

public void MoveObject_Shift()
{
    Debug.Log("Success: Inside Move Shift function");
    Debug.Log("Success: after moving position");

    // initialise max position to mouse position to avoid overlap with last iteration in same moved position
    positionMax = placementPose.position;
    // checking if mouse position already has any objects placed
    bool moveoverlap_found = false;
    do
    {
        moveoverlap_found = MoveObject_Overlap();
    }
    while (moveoverlap_found);

    hitObjectTransform = selectedObject.GetComponent<Transform>();
    Debug.Log("Success: Position before moving " + hitObjectTransform.position + ");
    // editing to update the position of moved object so it does not sit across tash plane.
    Vector3 currentPosition = placementPose.position;
    currentPosition.y = 0.00f;
    // end of edit
    hitObjectTransform.position = currentPosition;
    Debug.Log("Success: Position after moving " + hitObjectTransform.position + ");
    selectedObject.GetComponent<Renderer>().material.color = originalColor;
    isObjectSelected = false;
    // MoveObject_Drop();
}

void DestroyObject()
{
    Debug.Log("Success: Inside destroyed object");
    bool destroy_checkAbove = false;

destObject.position = placementPose.position;
    // removing any object from new empty project
    Collider[] hitColliders_destroy = Physics.OverlapBox(placementPose.position, objectToPlace.transform.localScale / 2f);
    foreach (Collider col in hitColliders_destroy)
    {
        Debug.Log("Success: tag of collider is " + col.gameObject.tag + ");
        // check if the collider belong to a cube and for cube collider check if size bound is same as last iteration (this is because
        if (col.gameObject.CompareTag("Cube1"))
        {
            originalPositionBeforeDestroy = col.gameObject.transform.position;
            destObject.position = col.bounds.max;
            destObject.position.y = col.bounds.max.y;
            placementPose.position = destObject.positionAbove;
            Debug.Log("Success: Setting placement pose value to check above. Original is " + originalPositionBeforeDestroy) + " new pos is " + placementPose.position);
            destroy_checkAbove = DestroyObject_CheckAbove();
            if (destroy_checkAbove) return;
        } else
        {
            Debug.Log("Success: Destroying object before moving objects above");
            Destroy(col.gameObject);
            DestroyObject_Move();
        }
        }
    }
}

public static bool DestroyObject_CheckAbove()
{
    Debug.Log("Success: Inside Destroy Object Check Above.");
    bool destroy_checkAbove = false;
    Collider[] hitColliders_destroyAbove = Physics.OverlapBox(placementPose.position, objectToPlace.transform.localScale / 2f);
    foreach (Collider col in hitColliders_destroyAbove)
    {
        Debug.Log("Success: tag of collider is " + col.gameObject.tag + ");
        // check if the collider belong to a cube and for cube collider check if size bound is same as last iteration (this is because
        if (col.gameObject.CompareTag("Cube1")) & col.bounds.max == destObjectMax)
        {
            Debug.Log("Success: Found object above the one to be destroyed.");
            destroyAboveCollider = col;
            destroy_checkAbove = true;
            break;
        }
    return destroy_checkAbove;
}
APPENDIX

Code Snippets of Analysis

```python
# Chi square test of independence for gender and AR use
import pandas as pd
import scipy.stats as stats

crosstab = pd.crosstab(new_tab["pre_gender"], new_tab["pre_ar_use"])

w, x, y, z = stats.chi2_contingency(crosstab)
print("The Chi Square value is:", w)
print("The p-value is:", x)

alpha=.02
if x < alpha:  # null hypothesis
    print("The null hypothesis can be rejected")
else:
    print("The null hypothesis is accepted")
```

```python
# create a correlation matrix for all the numerical column sets except the target variable

correlation = df.corr()
print("r")
print("Pearson Standard Correlation Coefficient Matrix")
print(correlation)
print("r")

# Generate a mask for the upper triangle
mask = np.triu(np.ones_like(correlation, dtype=bool))

# Set up matplotlib figure
f, ax = plt.subplots(figsize=(11, 9))

sns.set_style("dark")

# Generate a custom diverging colormap

cmap = sns.diverging_palette(230, 20, as_cmap=True)

# Heatmap with the mask and correct aspect ratio

gl.title("Heat Map of Correlation Matrix of numerical data")
heatmap = sns.heatmap(correlation, mask=mask, cmap=cmap, vmax=.3, center=0,
square=True, linewidth=.5, cbar_kws="shrink": .5),
annot = True, annot_kws = ("size": 12})

# Add ticks for labels

gl.set_xlabel(('tick.bottom': True), ("tick.left": True))

# Export heatmap as an image

gl.get_figure().savefig('stl.png', bbox_inches="tight")
```
## Questionnaire

### Public Town Art Game Evaluation

*Form description*

### Pre Game

This section is dedicated for general questions before playing the game.

**What is your age?**

Short answer text

**What is your gender?**

- [ ] Male
- [ ] Female
- [ ] Don’t want to disclose

**I use smartphone frequently.**

- [ ] Strongly Disagree
- [ ] Disagree
- [ ] Somewhat Disagree
- [ ] Neutral
- [ ] Somewhat Agree
- [ ] Agree
- [ ] Strongly Agree

**I often play mobile games.**

- [ ] Strongly Disagree
- [ ] Somewhat Disagree
- [ ] Disagree
- [ ] Neutral
- [ ] Agree
- [ ] Somewhat Agree
- [ ] Strongly Agree
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>I typically spend the following time playing mobile games each day.</td>
<td>0-1 hours, 1-2 hours, 2-3 hours, 3-4 hours, 4-5 hours, 5 or more hours</td>
</tr>
<tr>
<td>I have played an Augmented Reality (AR) game before.</td>
<td>No, Yes, Not Sure</td>
</tr>
<tr>
<td>I have experienced discrimination or prejudice based on my race, ethnicity, gender, sexuality, religion, or any other aspect of my identity.</td>
<td>Strongly Disagree, Disagree, Somewhat Disagree, Neutral, Somewhat Agree, Agree, Strongly Agree</td>
</tr>
<tr>
<td>I have felt socially isolated or disconnected from others.</td>
<td>Strongly Disagree, Disagree, Somewhat Disagree, Neutral, Somewhat Agree, Agree, Strongly Agree</td>
</tr>
</tbody>
</table>
I believe that social differences can be a barrier to social interaction and community building.

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

I often engage in social activities with friends or family members.

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

What types of social activities do you enjoy doing with others? (e.g., playing sports, going to the movies, having dinner parties, etc.)

Short answer text
I have used technology to meet new people or connect with others.

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

I have used technology to connect with people from different backgrounds or communities

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

**Usability**
This section is used to evaluate the game usability

How often would you play the game if it was readily available, working as intended, and with multiplayer support?

- Never
- Once
- Once every few months
- Once every month
- Several times per month
- Several times per week
- Daily
The User Interface (UI) is easy to use

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

I found that the various functions in this system were well integrated

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

It was easy to understand what the functions do

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree
How much time do you imagine that most people would need to learn to use this system?

- 0-5 minutes
- 5-15 minutes
- 15-20 minutes
- 30 minutes - 1 hour
- More than an hour
- Never

I was able to create objects easily

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

I was able to move objects easily

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree
I was able to destroy objects easily

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

I would recommend this game to others

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

What was your overall experience about the game?

Long answer text

Post Game
This section is dedicated to express some ideas and views after playing the game

Are there barriers that prevent you from interacting, or makes it difficult for me to interact with people from different backgrounds or communities?

- No
- Yes
If so, which barriers?

Long answer text

Creating art is a suitable activity to engage people from different backgrounds or communities to collaborate

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

Creating virtual art using an augmented reality application in a mobile device is a suitable activity to engage people from different backgrounds or communities to collaborate

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree
Collaborative creation of virtual art using AR encourages social interaction with others

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

Collaborative creation of virtual art using AR promotes social inclusion and reduces social differences

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

What features, if any, would you like to see in an AR game designed to increase social interaction? (e.g., particular game ideas, features etc.)

Long answer text

Building marble racetracks and racing together would encourage social interaction with people from different backgrounds or communities
Building Minecraft style creations together would encourage social interaction with people from different backgrounds or communities.
Creating realistic virtual art together would encourage social interaction with people from different backgrounds or communities.

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree

Do you have any ideas about other popular games which you feel will be interesting to play with other people using AR?

Long answer text:

It is important to feel a sense of belonging and inclusion in our social interactions in this world.

- Strongly Disagree
- Disagree
- Somewhat Disagree
- Neutral
- Somewhat Agree
- Agree
- Strongly Agree