# AUTISMSPHERE: AN IMMERSIVE INTERACTIVE SOCIAL SKILLSTRAINING PLATFORM FOR CHILDREN WITH AUTISM USING VIRTUAL REALITY

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## ABSTRACT

*In the summer of 2023, we volunteered at Xingle Family in Shanghai, an educational institution for autistic people. After mentoring and helping them develop their problem-solving and social skills, we were inspired to create a projectthat allows another avenue for those who could not easily visit Xingle Family. Using VR technology, we created threegames that help develop the aforementioned skills without having to leave their homes: a pipe-connecting game, a shape-driven balloon-popping game, and a color sorting game [1]. This project was made possible through Unity3D,a game engine running on C#, and Blender, an open-source 3D modeling tool [2]. To experiment with the games, weperformed playtesting with three friends that provided feedback through survey questions. We found that the games were generally easy to pick up but didn't warrant any replays due to both the lack of difficulty or the lack of appeal; harder levels may keep the player more engaged and thus help develop their motor and problem-solving skills. We want the project to prove that VR experiences can genuinely help development for autistic people with the advantage of it being more convenient for those who cannot easily go outside [3].*

## KEYWORDS

*Autism, Hand-eye coordination, Visual Perceptual Skills, Computer Games*

## 1. INTRODUCTION

In the summer of 2023, we volunteered at a non-profit, non-government organization (NGO) called Xing Le in Shanghai, which is an organization that specifically works with autistic patients [4]. Ou Yang–the founder–created the NGO to give his autistic son and others with autism the support and opportunity to develop their social, emotional, and motor skills. During my time at Xing Le, we had a great experience working with the patients, but we noticed certain individuals who rarely attended; they were unable to show up due to their severe conditions, so they were confined to their homes. We wanted to give those less fortunate the same opportunity for growth that the others had regardless of condition.

In our research findings, we found that video games can be an effective way to either evaluate or supplement the development of autistic children. Using technologies such as motion-tracking hardware (Xbox Kinect) or touch-based devices (iPad apps) simplified the mechanics needed to control a video game software [5]. Additionally, emphasis on expert opinions on techniques used to develop autistic children should be incorporated into the video games to ensure the correct design principles.

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Inclusive Design Approach for Developing Video Games for Children with Autism Spectrum Disorder [6].

Aim: Promote social initiation of children with ASD through collaborative gameplay using an Xbox Kinect.

Shortcomings: Limited age appeal, solely collaborative gameplay.

Improvement: Our project offers a more modern VR interface and targets a wider age range [7]. Pilot Study on Evaluating Children with Autism Spectrum Disorder Using Computer Games.

Aim: Evaluate children with autism using pattern recognition computer games.

Shortcomings: Primarily single player, lacks advanced technology.

Improvement: Our project utilizes VR technology, providing a more advanced and immersive approach.

Effects of the Video Game ‘Mindlight’ on Anxiety of Children with Autism Spectrum Disorder.

Aim: Investigate the impact of the video game "Mindlight" on anxiety symptoms in children with ASD.

Shortcomings: Single-player focus, limited exploration of VR technology. Improvement: Our project integrates VR for a more immersive therapeutic intervention.

Our project, while drawing inspiration from these methodologies, strives to combine the collaborative approach, advanced technology, and immersive experiences to cater to a wider range of ages with ASD. By integrating VR and emphasizing pattern recognition games, our project offers an innovative, engaging, and inclusive solution that surpasses the limitations of these methodologies.

Using virtual reality, we sought to develop one’s hand-eye coordination, organization, and patience [8]. We created three virtual reality games that challenge those aspects without having to go to another physical location. Most people at home have access to a personal computer or a smartphone, which VR systems can utilize. We believe that VR systems will evolve to become an important technology from today and to the future, so creating a solution based on this tech gives a more potential convenient path for development.

As stated before, the three different games we developed tackled specific skills such as motor, organization, and recognition. The first would be a pipe connecting game, the second a balloon popping game, and third a color sorting game. In order to create the project, we utilized the Unity3D game engine to help speed up the development process [9]. Additionally, we created our own assets by using Blender, a 3D-modeling tool.

VR as a tool can be a great doorway for immersion, which helps with blurring the lines between “training” and “having fun”; a person may not feel inclined to improve their skills in something they don’t personally find fun. Thus, VR-games can make it easier to bridge the gap and discover the viability of the technology. Other methods have used primitive games that utilize point and click mechanics, but moving around in a 3D-environment can be more engaging and immersive [10].

The survey experiment aimed to assess different skills such as hand-eye coordination, pattern recognition, and problem-solving within my game, along with gauging the difficulty levels and overall enjoyment. Conducted among friends, the survey revealed that participants were generally pleased with the game; however, a key finding was the lack of replay value. Although the game was fun initially, it did not attract players back for repeated sessions. Despite this, the survey was successful in its objective. The feedback gathered helped pinpoint areas for improvement, primarily focusing on enhancing the game's replayability factor. Insights from the survey led to bug fixes, fine-tuning gameplay mechanics, and incorporating elements to make the game more engaging for longer durations. As a result, the experiment not only provided valuable feedback but also served as a catalyst for refining the game based on user preferences and experiences.

## 2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

### 2.1. Freedom

How much freedom does the player have when placing pipes

When designing the levels of the pipe game, we wanted it to be possible for all pipes to rotate to give more options to the player. That meant that certain pipes like the T-pipe could have different branching directions where the player must connect the final pipes correctly in both branches. However, to maintain a consistent solution, pipes can only be placed at certain nodes (but any type of pipe can be placed there). Additionally, there is a fixed amount of each pipe in each of the levels that correspond exactly to the solution; in the future we could have multiple solutions with differing sets of pipes.

### 2.2. The Difficulty

The game seems too simple; how can the difficulty of the balloon game be increased?

The balloon game increases in difficulty by forcing the player to recognize what shape the balloon has; a random set of shapes are chosen as “correct” balloons, and shooting the “incorrect” balloons loses you points. This heavily increases the difficulty since the player cannot hastily shoot every single balloon and also trains their recognition abilities.

How does this train hand/eye coordination?

The balloon game’s primary mechanic is aiming the VR controller toward the balloon and pulling the trigger to pop it; as the difficulty ramps up, the speed and size of the balloon increase and decrease, respectively. This trains hand/eye coordination since the player must “aim” and “click”.

### 2.3. Person’s Skills

How does the sorting game help a person’s skills?

We wanted to target both a person’s recognition skills (through color) and most importantly, their organization skills. Sorting everything by color is a one of the paths that can help a person organize their things, so we believed that this game can build a habit of it whilst it being fun.

## 3. SOLUTION

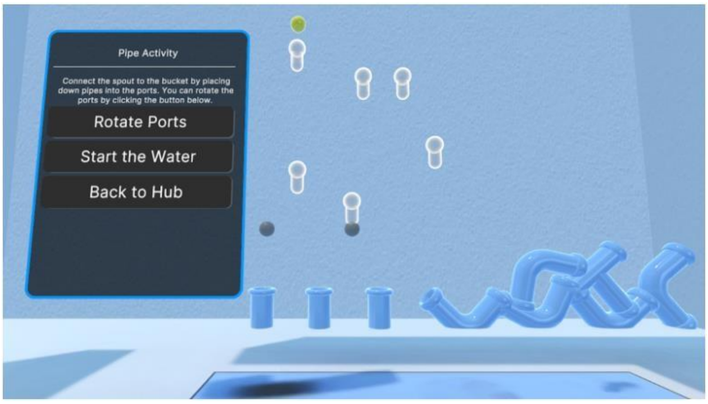
The game has two versions; one version is playable without a VR-headest, and the other requires it [15]. The player starts in a room where they can choose what game they want to play and the corresponding level. For example, you can look at the "Pipe Levels", and you can select Level 1, Level 2, and so on. Once a level is selected, the player will teleport into a room based on the type of game. There are three different games: a pipe game, a balloon popping game, and a color sorting game.

In the pipe game, the player will have to place pipes in certain locations in order to get the flow of water from the beginning to the final water collector. There are a few types of pipes such as the straight pipe, the T-pipe, and the L-pipe. Each of the pipes direct water in different ways and ideally flow to another pipe location node. The T-pipe in particular can split water into multiple paths, meaning that some level designs can require the player to fill more than one water container at the end. The levels start very simple and ramp up in difficulty by increasing the length of the water path and also introducing branching paths.

In the balloon game, the player spawns in the middle of the room and selects "Begin". Then, balloons of different shapes, colors and sizes will start spawning around the player. The player must point their cursor to the balloon and pull the trigger to pop it; they must not let the balloons get too high or they will miss out on points. A certain point threshold must be met in order to continue to the next level.

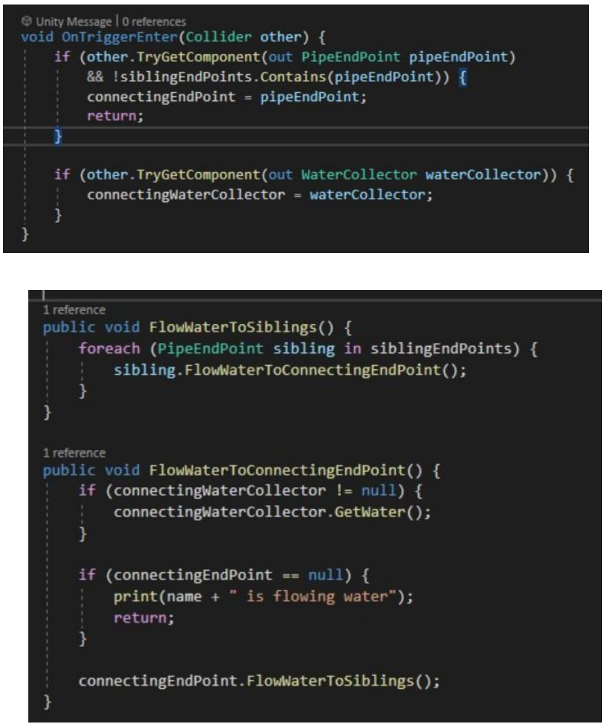
In the color sorting game, the player's objective is to place the correct colors of figures onto their corresponding color platform. After putting them on the correct platforms, the player can check if everything is sorted by pressing the "Check Results" button.

In the pipe game, there are specific nodes that a pipe can be placed in. The script allows the player to snap a pipe they are holding onto the node and also rotate it by pressing the button. The pipes will be able to transfer water from the entrance of the water to the other end of the pipe.


Pipe Activity

Connect the spout to the bucket by placing down pipes into the ports. You can rotate the ports by clicking the button below.

Figure 1. Screenshot of the game 1



```
Unity Message | 0 references
void OnTriggerEnter(Collider other) {
    if (other.TryGetComponent(out PipeEndPoint pipeEndPoint)
        && !siblingEndPoints.Contains(pipeEndPoint)) {
        connectingEndPoint = pipeEndPoint;
        return;
    }

    if (other.TryGetComponent(out WaterCollector waterCollector)) {
        connectingWaterCollector = waterCollector;
    }
}
```

```
1 reference
public void FlowWaterToSiblings() {
    foreach (PipeEndPoint sibling in siblingEndPoints) {
        sibling.FlowWaterToConnectingEndPoint();
    }
}

1 reference
public void FlowWaterToConnectingEndPoint() {
    if (connectingWaterCollector != null) {
        connectingWaterCollector.GetWater();
    }

    if (connectingEndPoint == null) {
        print(name + " is flowing water");
        return;
    }

    connectingEndPoint.FlowWaterToSiblings();
}
```

Figure 2. Screenshot of code 1

“OnTriggerEnter” is a function that runs everytime another collider touches the collider attached to the pipe. The triggers are specifically located on each end of the pipes. The “if” statement will try to see if the triggering collider was also a “PipeEndPoint” to make sure only pipes are affected by this code. This new pipe is added as a “sibling” of the pipe so that the script can have water flow out of that specific connected side. If it’s the “water collecting point” (which is the end pipe of the level), it will fill water in that object.

Once the “Start the Water” button is pressed, water will attempt to flow through the pipe that is connected to it, which is shown in the “FlowWaterToConnectingEndPoint” function. If it’s the “water collecting point”, we set it to “true” to mark the pipe puzzle complete. If it’s not, then have that pipe repeat the process with its own siblings by calling the “FlowWaterToSiblings” function. For the balloon popping game to run, we created a balloon generation script to deal with spawning balloons with different shapes, sizes, and speeds. For a win condition, the hits and misses were tracked where the player must not surpass a certain amount of misses, and must reach a certain hit threshold.

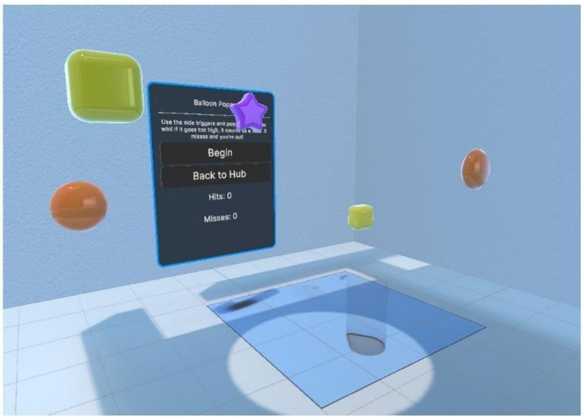
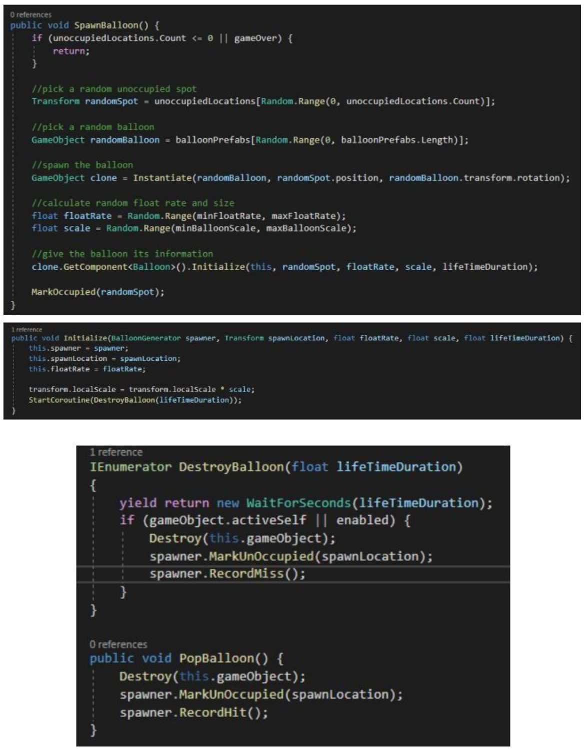


Figure 3. Screenshot of the game 2



```
0 references
public void SpawnBalloon() {
    if (unoccupiedLocations.Count <= 0 || gameOver) {
        return;
    }

    //pick a random unoccupied spot
    Transform randomSpot = unoccupiedLocations[Random.Range(0, unoccupiedLocations.Count)];

    //pick a random balloon
    GameObject randomBalloon = balloonPrefabs[Random.Range(0, balloonPrefabs.Length)];

    //spawn the balloon
    GameObject clone = Instantiate(randomBalloon, randomSpot.position, randomBalloon.transform.rotation);

    //calculate random float rate and size
    float floatRate = Random.Range(minFloatRate, maxFloatRate);
    float scale = Random.Range(minBalloonScale, maxBalloonScale);

    //give the balloon its information
    clone.GetComponent<Balloon>().Initialize(this, randomSpot, floatRate, scale, lifeTimeDuration);

    MarkOccupied(randomSpot);
}
```

```
1 reference
public void Initialize(BalloonGenerator spawner, Transform spawnLocation, float floatRate, float scale, float lifeTimeDuration) {
    this.spawner = spawner;
    this.spawnLocation = spawnLocation;
    this.floatRate = floatRate;

    transform.localScale = transform.localScale * scale;
    StartCoroutine(DestroyBalloon(lifeTimeDuration));
}
```

```
1 reference
IEnumerator DestroyBalloon(float lifeTimeDuration)
{
    yield return new WaitForSeconds(lifeTimeDuration);
    if (gameObject.activeSelf || enabled) {
        Destroy(this.gameObject);
        spawner.MarkUnOccupied(spawnLocation);
        spawner.RecordMiss();
    }
}

0 references
public void PopBalloon() {
    Destroy(this.gameObject);
    spawner.MarkUnOccupied(spawnLocation);
    spawner.RecordHit();
}
```

Figure 4. Screenshot of code 2

This block of code deals with spawning a balloon when the spawn timer is reached. A random location is chosen from a predetermined list of transforms, which are placed around the player as GameObjects. Then, a random balloon from a list of prefabs is chosen, which consists of different shapes like a heart, circle, or cube. This is finally instantiated as a GameObject on top of the previously chosen location. We generate the speed and size, and finally send this information to a helper function inside of the Balloon script, which will fully initialize the attributes of the balloon. Additionally, we start a Coroutine that destroys the balloon automatically after a set amount of time.

To make sure that another balloon is not in the same spot, we mark the randomly chosen location as “Occupied”, where we remove it from the “unoccupiedLocations” list and add it to an “occupiedLocations” list.

If the balloon is popped or despawns after a certain time, the location becomes unoccupied again, so we re-add the location to the “unoccupiedLocations” list so it can be used again. We also mark a “hit” or “miss” based on if it despawned or got popped.

The third game has the player sort figures of different colors on their corresponding platforms. Object detection using colliders were used to determine if the player had successfully done this task. This game increased in difficulty by increasing the amount of colors and figures to sort. The grouping was primarily done by checking an enum defined in the “Person” script.

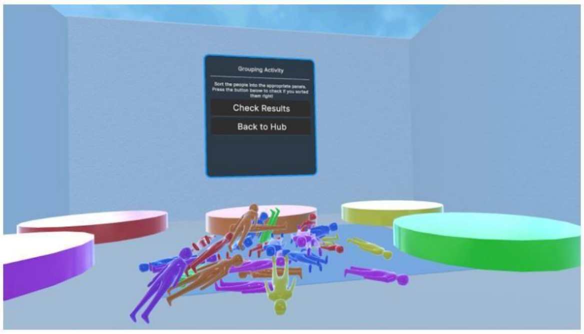
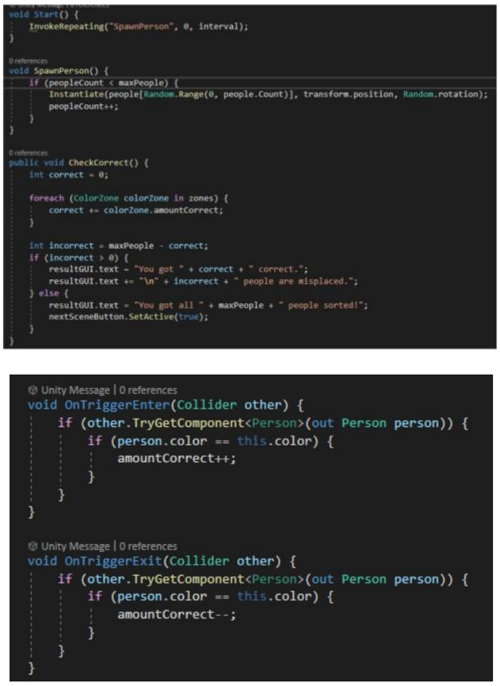

Grouping Activity
Sort the people into the appropriate panels. Press the button below to check if you sorted them right!
Check Results
Back to Hub

Figure 5. Screenshot of the game 3



```
void Start() {
    InvokeRepeating("SpawnPerson", 0, interval);
}

0 references
void SpawnPerson() {
    if (peopleCount < maxPeople) {
        Instantiate(people[Random.Range(0, people.Count)], transform.position, Random.rotation);
        peopleCount++;
    }
}

0 references
public void CheckCorrect() {
    int correct = 0;

    foreach (ColorZone colorZone in zones) {
        correct += colorZone.amountCorrect;
    }

    int incorrect = maxPeople - correct;
    if (incorrect > 0) {
        resultGUI.text = "You got " + correct + " correct.";
        resultGUI.text += "\n" + incorrect + " people are misplaced.";
    } else {
        resultGUI.text = "You got all " + maxPeople + " people sorted!";
        nextSceneButton.SetActive(true);
    }
}
```

```
Unity Message | 0 references
void OnTriggerEnter(Collider other) {
    if (other.TryGetComponent<Person>(out Person person)) {
        if (person.color == this.color) {
            amountCorrect++;
        }
    }
}

Unity Message | 0 references
void OnTriggerExit(Collider other) {
    if (other.TryGetComponent<Person>(out Person person)) {
        if (person.color == this.color) {
            amountCorrect--;
        }
    }
}
```

Figure 6. Screenshot of code 3

In the PersonSpawner script, when the level begins, the “Start” function runs where it repeats the “SpawnPerson” function. There, it will spawn a random new person from a list of Person GameObjects of different colors until it reaches a max value, “maxPeople”. The list consists of different colored people using materials in Unity.

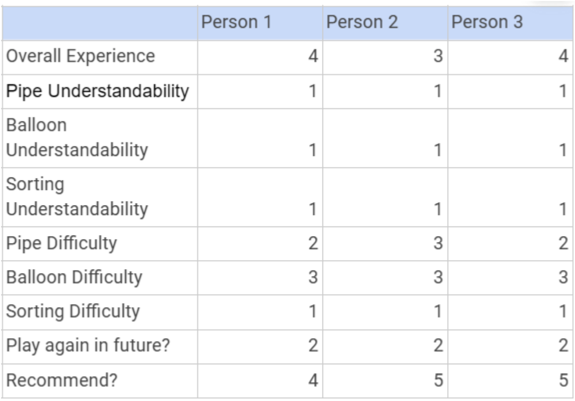
“OnTriggerEnter” is a function in the ColorZone script which is attached to the platform game objects. When an object enters its collision area, it will try to check if the “Person” script is attached. If it does, we increase a variable that keeps track of the amount correct. We can calculate the number of incorrect people misplaced with (total amount spawned - number of correct). If the calculated incorrect variable is positive, the UI displays a message that X amount of people are in the wrong spot; if there are no misplaced people, the next level button is activated and can be pressed to continue.

## 4. EXPERIMENT

Our perception of the games we created are biased to our own designs. Therefore, we decided to playtest our project with others to get a more general perspective. We specifically wanted to test if our project could be effective in helping autistic patients develop better sorting skills, motor skills, and problem-solving skills.

Before we started the survey, we created questions to understand the general audience’s opinion of the project. These questions consisted of topics ranging from the tester’s opinion on each of the games, if they would play it again, and if they would recommend it to anyone else.
For convenience, we asked close friends and family to participate in the testing group.

When conducting the experiment, we had the tester play all three games through the VR headset, then presented them with 9 questions and asked for honest opinions. We asked them to answer these questions on a scale of 1-5 and explain their reasoning.



| | Person 1 | Person 2 | Person 3 |
|---|---|---|---|
| Overall Experience | 4 | 3 | 4 |
| Pipe Understandability | 1 | 1 | 1 |
| Balloon Understandability | 1 | 1 | 1 |
| Sorting Understandability | 1 | 1 | 1 |
| Pipe Difficulty | 2 | 3 | 2 |
| Balloon Difficulty | 3 | 3 | 3 |
| Sorting Difficulty | 1 | 1 | 1 |
| Play again in future? | 2 | 2 | 2 |
| Recommend? | 4 | 5 | 5 |

Figure 7. Table of experiment

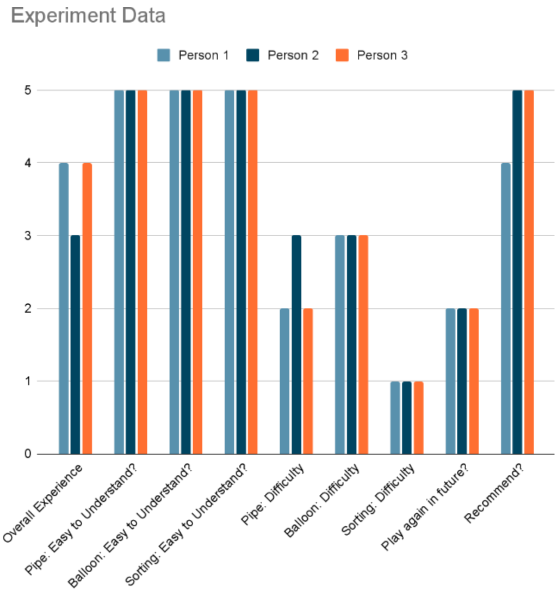


Figure 8. Experiment data

Questions 2, 3, and 4 have the highest scores, which indicate how easy it was to understand each of the games. The testers all found the games extremely easy to understand and pick up. However, the results are based on testers that are not autistic, which is not our targeted demographic. Therefore, the testers' opinions of the accessibility of our games may not be an accurate depiction of the entire population.

The sorting game recorded the lowest scores in difficulty within the group. We expected each of the games to rate at a medium difficulty, so we were surprised to see how much easier the sorting game was compared to the others. Consequently, we want to increase the difficulty of that game to ensure the stimulation of logical skills.

The testers found that the games aren't enticing enough to warrant a replay, as indicated on Question 9. We realized that the games didn't have an appealing goal to work toward; the absence of a clear finish line meant that there was no clear motivation for playing the game in the first place. This is an issue regardless of the demographic, so we want to fix this before appealing to those with autism.

## 5. Related Work

These researchers created a game called "Pico's Adventure" [11]. The game is based on promoting the social initiation of children with Autism Spectrum Disorder. The children give advice and instructions to the adult in order to progress in the game. There are a few key differences between their project and our project; they utilized an Xbox Kinect, while we used a VR headset for the user interface. Their game is designed to be more collaborative, while our game is directed toward solo play. They had more childlike elements to appeal to autistic children, while we didn't have any. Despite these key differences, our game improved on some aspects of "Pico's Adventure".

Our project is more modern, due to the use of a VR headset, and our game appeals to more age ranges instead of appealing directly to children.

The researchers of this article claim that the traditional methods of evaluating those with autism are “time-consuming and clinically demanding”; these methods are heavily dependent on the evaluators’ ability [12]. This study focuses on whether or not a computer game is more effective in evaluating versus an experienced evaluator. Similar to our project, they used pattern recognition games that involve object connotations. However, they included social interaction as a key component in most of their games, while our games were purely single-player. In contrast, our use of virtual reality technology is more advanced than the primitive mechanics of their study’s games.

The research study "Effects of the video game ‘Mindlight’ on anxiety of children with an autism spectrum disorder: A randomized controlled trial" investigates the impact of the video game "Mindlight" on anxiety symptoms in children with ASD [13]. The study employs a rigorous randomized controlled trial design to compare the effectiveness of the video game intervention with an active control condition using a non-therapeutic game. While the study results did not reveal significant differences in the decrease of anxiety between the experimental and control conditions according to children, parents reported greater improvements in anxiety symptoms for children who played Mindlight at the three-month follow-up. The study also addresses the limitations and strengths of the research, emphasizing the need for further exploration of the mechanisms contributing to the decrease in anxiety symptoms and the future directions for investigating the efficacy and long-term effects of the intervention. In comparison to our project, the research paper's study methodology and findings shed light on the potential of video games as an intervention for children with ASD, aligning with our interest in exploring innovative approaches to supporting individuals with neurodevelopmental conditions. However, while the research study focused on single-player games, our project's use of virtual reality technology and emphasis on pattern recognition games with object connotations provides a more advanced and immersive approach to engaging individuals with autism in therapeutic interventions.

## 6. CONCLUSIONS

When considering the limitations of my project involving the development of three mini-games for VR tailored to the autistic community, it becomes apparent that my constrained background in coding posed a significant challenge. Given my limited experience in coding, especially for VR games, I had to devote considerable time to researching and learning the necessary skills to bring these games to life effectively [14]. If granted additional time for further development, I would prioritize delving deeper into refining the finer details of each game. This includes enhancing the aesthetics to create a more visually pleasing experience for the players while also focusing on optimizing the performance for seamless gameplay.

Reflecting on the project, if I were to start over, I would approach the planning phase meticulously before diving into the coding process. The initial lack of a detailed plan made the development journey more arduous than necessary, leading to organizational challenges along the way. For future expansion of the program, I aspire to broaden its scope by incorporating more interactive elements that cater specifically to the diverse needs of individuals within the autistic community. This could involve incorporating feedback mechanisms, additional educational elements, or even collaborative multiplayer features to enhance engagement and inclusivity within the gaming experience.

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