Color Blindness Bartender: An Embodied VR Game Experience

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Abstract

Color blindness is a very common condition, as almost one in ten people have some level of color blindness or visual impairment. However, there are many tasks in daily life that require the abilities of color recognition and visual discrimination. In order to understand the inconvenience that color-blind people experience in daily life, we developed a virtual reality (VR) application that provides the sense of embodiment of a color-blind person. Specifically, we designed a color-based task for users to complete under different types of color blindness in which users make colorful cocktails for customers and need to switch between different color blindness modalities of the application to distinguish different colors. Our application aims to embody users to color blindness in order to raise awareness on such color vision deficiency.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual Reality

1 Introduction

Color blindness causes a lot of problems in a person's life. There are many kinds of information that are transmitted through color, such as traffic lights. If someone cannot perceive color differences, then it will be hard or even impossible for them to complete color-based tasks.

In order to understand the inconvenience of being unable to distinguish different colors in daily life, we developed an application for people with normal color vision that requires users to recognize and distinguish different colors to finish a color-based task. Thus, our application aims to provide a sense of embodiment [6] of color blindness using VR technology, which requires users to complete color-based tasks, such as making different cocktails of different colors for virtual customers.

2 Color Blindness

Color blindness is defined as an inability or decreased ability to distinguish different colors [3]. It is quite common among people. According to Ahsana et al. [1], the frequency of color blindness differs between different countries and genders. Europeans have the highest rate of color blindness worldwide at 7.4% and the frequency of color blindness is much higher in males than in females [5]. Generally, color blindness is incurable, and the most common cause of it is genetic inheritance [9].

Many applications have been created assist color-blind people. Gary W. Meyer and Donald P. Greenberg claimed that it is possible to synthesize a color-blind view of the world through the use of computer-graphics displays [7]. Using electronic glasses and multispectral lens arrays have also been proposed for color-blind vision correction [4]. Many color blindness test applications have been summarized in Plothe [13]. For example, color-vision adaptation methods for digital game have been developed to assist people with color-blindness [12].

2.1 Colorblindness Types

Cone cells are responsible for color recognition. There are three types of cones [2], which respond to low, medium, and long wavelengths, respectively, and missing one of the cone types results in one of three different kinds of color blindness: tritanopia, deuteranopia, and protanopia. Tritanopia refers to missing short-wavelength cones, and results in an inability to distinguish the colors of blue and yellow. Deuteranopia and protanopia refer to missing medium-wavelength cones and long-wavelength cones, respectively. However, both deuteranopia and protanopia result in patients' inability to see the colors of red and green, because the medium wavelength is close to the color green and the long wavelength is close to the color red, and red and green are inverse colors that cannot be seen at the same time. Thus, there is a greater similarity in the type of visual deficiency between deuteranopia and protanopia compared to tritanopia [10].

2.2 Colorblindness Rendering

It is possible to eliminate certain color information from color spaces to create different color effects for the different types of color blindness. Color-blind vision can be simulated using image-processing techniques. In our application, we developed our color blindness rendering effect to simulate the vision of color-blind people. The algorithm behind the simulation can be summarized as follows:

1. Convert RGB color space to LMS color space, which represents the response of the three types of cones of the human eye, named for their responsivity peaks at long, medium, and short wavelengths.

2. Do matrix multiplications in the LMS color space to eliminate certain types of colors from the current color space. The matrix expressions of protanopia, deuteranopia, and tritanopia are all a 3×3 matrix, which can be extracted [8].

3. Convert LMS back to RGB.

3 Implementation Details

Our application is implemented using Unity Engine, the HTC Vive head-mounted display, and the HTC Vive base to track the movement of the user. We designed eight cocktails with different combinations of colors and eight wines of different colors. The rendering effects of our cocktails and wines are shown in Figure 1. There are three main parts in our project, described in the sections below.

3.1 Fluid Simulation

The common way to simulate fluid is to use particles, and smoothed particle hydrodynamics (particle-based fluid simulation) is the most representative one among this series of methods [11]. However, this method needs lots of computational resources and is very time consuming. For an easier approach with higher efficiency for our application, we simplified the model and shot particles from the bottle mouth and added a random velocity with gravity. Once particles

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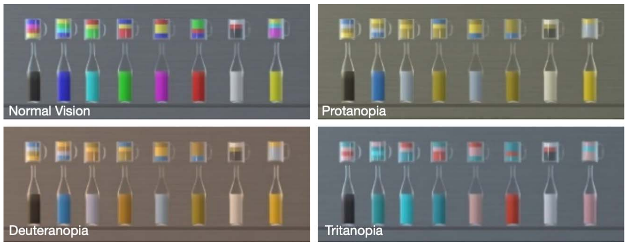

Figure 1: Color blindness rendering effects. The upper layers are cocktail types and the lower layers are wine types.

enter the cup they disappear, and a cylinder placed inside the cup enlarges. This simple approach creates an illusion that the liquid is accumulated. The effect of our method is shown in Figure 2.

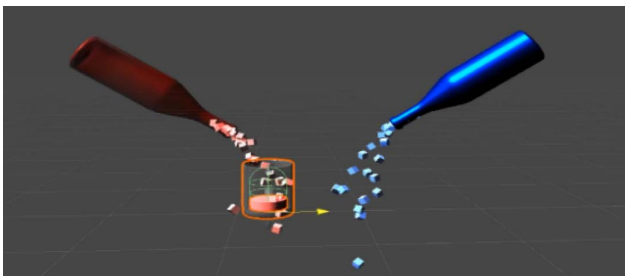

Figure 2: Fluid-simulation effect.

3.2 Score-Counting System

In order to inform the user whether the cocktail they made correctly matches the requirements of the customer, we designed a score-counting system to evaluate user performance. We set up a threshold and we check whether the difference between the order requirements and the cocktail made by the user are within the threshold. Scores are earned in order to inform the user when their action is correct. The script for this function is attached to the service desk in the virtual environment, and the score-counting is shown in Figure 3.

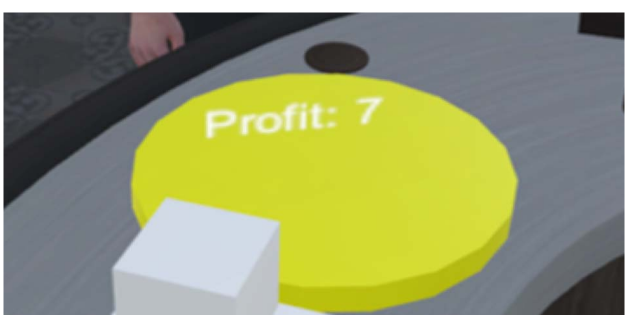

Figure 3: Score-counting system.

3.3 Pathfinding and Animation

In order to efficiently manage the movement of virtual customers, we used the NavMesh functionality of Unity3D to manage the path finding process. Moreover, the Mecanim animation engine of Unity3D was used to animate the virtual characters (customers of the virtual bar). The animation components are attached to the virtual characters. We pre-scripted our virtual characters (customers) to request certain type of cocktails under the mode of tritanopia, as shown in Figure 4.

Figure 4: Virtual customer requests a certain type of cocktail.

4 Conclusion

We created a VR bartender application designed with color-based tasks that require the user to correctly recognize and distinguish different colors in order to make cocktails according to customers' orders. Background information about color blindness and implementation details are described above. Users of our game make colorful cocktails for customers according to their needs, which requires users to change between different modalities of color blindness to distinguish colors and finish the tasks.

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