Investigating How Crosshair Color Influences Human Perception Across Different Targets and Backgrounds

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Abstract
There are several fields where pinpoint accuracy in targeting is essential. gaming, medical procedure, military activities and more. Targeting with crosshairs is common, and the success of your shot can be affected by elements like the color of your crosshairs. The purpose of this research was to examine how changing crosshair colors affect how people perceive their targets and backgrounds. Eight people were enlisted to use one of five different colored crosshairs to shoot at five

different colored targets displayed on three different backdrops. The aiming times of the participants were collected and analyzed to see how the crosshair color and background affected the participants' accuracy. Aiming times were found to be considerably affected by crosshair color, with red and green crosshairs leading to the quickest aiming times. In addition, black and white backgrounds were more sensitive to crosshair color than green ones. These results have applications in a variety of fields, including the defense industry, where precise aiming is essential. Professionals can create more efficient aiming systems and training programs by investigating the impact of crosshair color on human perception.

Author Keywords
crosshair; background; color; visual targets; color combinations; visibility enhancement.

CSS Concepts
• **Human-centered computing~Human computer interaction (HCI)**; *Haptic devices*; User studies;

1. Introduction
The idea of the metaverse and 3D immersive environments has received a lot of attention lately and offers previously unheard-of possibilities for virtual social interactions and digital experiences. Users frequently engage in a variety of activities while navigating these virtual worlds, from gaming to collaborative work. However, users in these environments must contend with simulation sickness, a type of motion sickness brought on by inconsistencies between visual and vestibular cues.[1] Users may feel nausea, confusion, and other unpleasant side effects as a result of this problem.[2][3]

A potential solution for mitigating the symptoms of simulation sickness involves incorporating a crosshair within the 3D environment. A crosshair is a visual cue that is commonly presented as two intersecting lines or a small circular shape and is centrally located within the user's visual field. The implementation of crosshairs in virtual environments aids in user navigation by providing a consistent focal point, thereby reducing the possibility of experiencing simulation sickness. Moreover, the precision of tracking was comparatively reduced when the target was in motion at a higher speed and when the participants employed a crosshair. [4] Intelligent crosshair design is deemed crucial for enhancing user experience and promoting the broader acceptance of the metaverse and 3D immersive environments.

To achieve effectiveness and user usability, numerous elements should be taken into account while designing crosshairs for 3D immersive situations. First, the crosshair's visual look should be clearly seen against a variety of backdrops by using a color scheme that improves contrast or an outline that sets it apart from the background. Second, to prevent obscuring the user's vision or overpowering their visual senses, the crosshair should be inconspicuous, maintaining a balance between visibility and minimalism. Additionally, the ability for users to select the crosshair design, size, and color that best meets their needs and preferences can considerably improve the user experience. The chance of simulation sickness can be further decreased by this customization, which can also boost comfort and usability. Last but not least, programmers ought to think about including dynamic crosshair capability, which would let the crosshair adjust to various circumstances or give the user contextual input.

Crosshairs can successfully reduce simulation sickness and enhance the overall experience in the metaverse and 3D immersive settings by incorporating these design components.

The examination of the correlation between crosshair color and diverse background settings is a significant field of research aimed at improving visibility and user experience in virtual environments. Through the analysis of various color combinations and contrast levels, it is feasible to determine the most effective crosshair designs that are appropriate for a diverse array of virtual environments. An exhaustive examination in this domain has the potential to furnish developers with valuable design principles and guidelines, guaranteeing the consistent ease of recognition and efficacy of crosshairs, irrespective of the background.

2. Related Work

Numerous prior research endeavors have focused on investigating the impact of crosshair attributes on the accuracy of pointing in simulated settings. Mayer et al. demonstrated that the presence of crosshair with offset compensation can significantly enhance pointing accuracy in 3D environments when no cursor is provided. [5] Similarly, Tether et al. investigated the comparison between stereo- and mono-rendered cursors across various perspectives.[6]

Despite an extensive amount of research on the functionality and performance of crosshairs, there has been an absence of investigation into the correlation between crosshair design and background aesthetics. Further investigation is warranted in this region, as comprehending the interplay between crosshair design and the visual backdrop may result in more efficient and attractive crosshairs in virtual environments. Through further exploration of this subject matter, scholars have the potential to reveal significant findings that enhance user experiences and interactions in 3D immersive environments.

Mackenzie et al. propose the method to evaluate the precision for target pointing tasks. One of the essential parameters is the target re-entry (TRE), which denotes the duration required for the user to navigate the crosshair to a designated area, exit, and proceed to the subsequent target. [7]

Furthermore, Fitt's law can be used as an empirical model that delineates the interplay between the velocity and precision of pointing tasks. According to Fitt’s law, the index of difficulty ID_e is denoted as:

$$ID_e = \log_2\left(\frac{d}{s} + 1.0\right)$$

with d and s are the distance from the starting point to the target and the size (diameter) of the target, respectively. [7]

Murata et al. propose the extension of this index for 3D scenario:

$$ID_3 = \log_2\left(\frac{d}{s} + 1.0\right) + csin\theta$$

With θ as the angle between the target and the center of the screen and c is an arbitrary constant to be determined through linear regression. [8]

3. Performance Study

For our study we developed an environment called "Precision Pro" which is an aim trainer similar to AimLab[10]. Precision Pro, built with Unity 2021.3.14f1, includes a menu that provides options for the testing environment. Users can select from a variety of buttons to customize the environment to their preferences.

3.1 Crosshair

Crosshairs can be made in a variety of colors and designs, not just the traditional red, green, blue, black, and white. This can help people who have trouble distinguishing between colors. Protanopia, Deuteranopia and Tritanopia (blue-yellow colorblindness) are three examples of colorblindness that could be accommodated by providing custom color schemes. The crosshair we chose is a cross crosshair. It was made using Rect Transform which had a white rectangle offset to the center of the screen then was duplicated and rotated to all 4 directions, so it forms a crosshair.

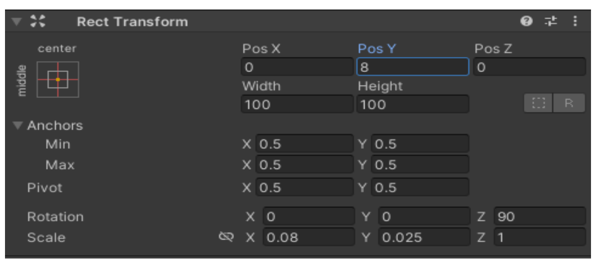

Figure 1: Crosshair implementation. Each rectangle has the following component with interchangeable x and y axis to form the other part of the crosshair.

In the experiment, the color of the crosshair will change once a set of targets have been hit with the current-colored crosshair. The colors switch from red to green to blue to black and finally to white and repeat for each environment.

Figure 2: Crosshair color.

3.2 Environment

At the start of the experiment, the walls around the space are set to black as the default background color. The environment includes a 3D humanoid and a shooting mechanism script that were obtained from the Unity Asset Store [11]. During the progression of the experiment the walls of the environment change from black to white to green. To determine where the participant has fired in the 3D space, we use a RayCast that originates from the tip of the gun and extends towards the direction where the humanoid is aiming.

During test planning, we made the decision to create an environment that accommodates participants with the three most prevalent forms of color blindness: protanopia, deuteranopia, and tritanopia. The participants selected their preferred environment then tested the experiment.

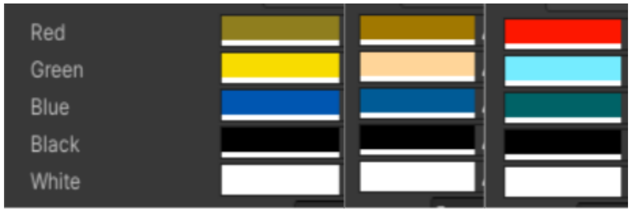

Figure 3: Color theme for color blindness subjects: protanopia, deuteranopia, and tritanopia respectively

4. Experiment

This study can analyze a number of dependent and independent variables that are present in the program. The program's customization feature, which includes three various background colors, five crosshair colors for each background, and ten targets to strike for each crosshair color, acts as the independent variable in this scenario. The performance, accuracy, and general satisfaction of the user with the software are the dependent variables. This will allow examining the effects of changing the customization choices on the dependent variables by changing the independent variable which will help gain insights into how to best optimize the program for user engagement and effectiveness.

In this study people had to answer a 20-question pre-experiment questionnaire about themselves and their experience with first-person shooter aiming and field of view controls. This will let us know about the participants' background and preferences. The participants had to tell us whether they were colorblind so the team could make sure they have suitable alternative crosshair colors. The mouse sensitivity was customized by the participants as we wanted the best performance from our participants based on the color of environment and crosshair color. The target color was set to yellow by default since it is the brightest color to the human eye [17]. The targets spawn randomly around a preset 3d space, and the participants have to shoot all the targets till all 3 environment colors have been tested. Finally, the time taken for each crosshair color is exported to a CSV file, enabling evaluation of the participant's performance during the experiment.

5. Evaluation

The findings demonstrate how long it took individuals on average to locate objects on various backgrounds using various crosshair colors. It is crucial to keep in mind that the amount of time required demonstrates how simple it was for the participants to locate targets on various backgrounds using various colored crosshairs. People needed, on average, 0:08 seconds to locate the target on a black background while the crosshair was also black. The next quickest time with a red crosshair was an average of 0:09 seconds.

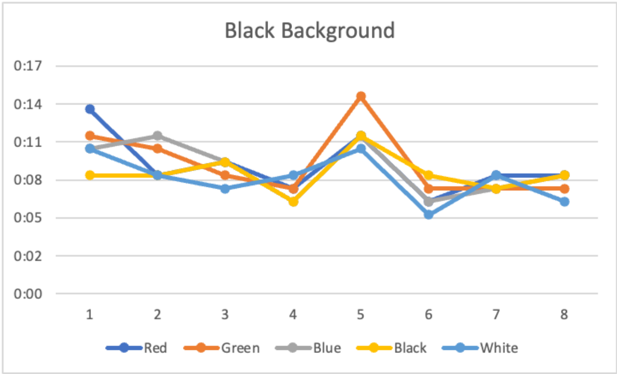

Figure 4: Average time users took on the different crosshair colors for the black background

The average time with blue and green crosshairs was 0:09 seconds, which was the quickest. The quickest times were seen with white crosshairs, with an average of 0:10 seconds. These findings show that crosshairs with a black background stand out more than crosshairs with a blue or green background. People needed, on average, 0:08 seconds to locate the target on a black background while the crosshair was also black. The next quickest time with a red crosshair was an average of 0:09 seconds. The average time with blue and green crosshairs was 0:09 seconds, which was the quickest. The quickest times were seen with white crosshairs, with an average of 0:10 seconds. These findings show that crosshairs with a black background stand out more than crosshairs with a blue or green background.

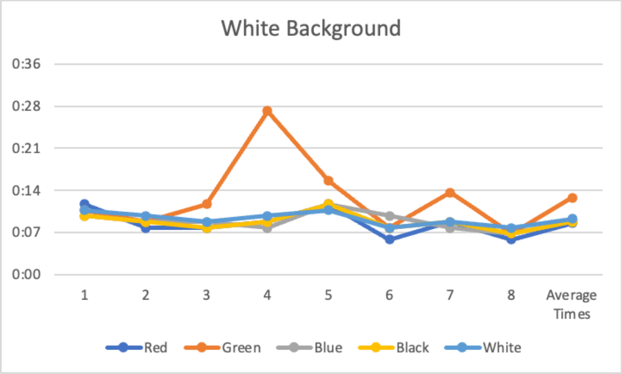

Figure 5: Average time users took on the different crosshair colors for the white background

Participants took an average of 0:08 seconds to locate the object with a blue crosshair on a green background. The next quickest times were recorded using black, red, and green markers, with an average time of 0:09 seconds. The average time was 0:09 seconds with white crosshairs, which was the quickest. These findings show that on a green background, blue crosshairs stand out the most while white crosshairs do not.

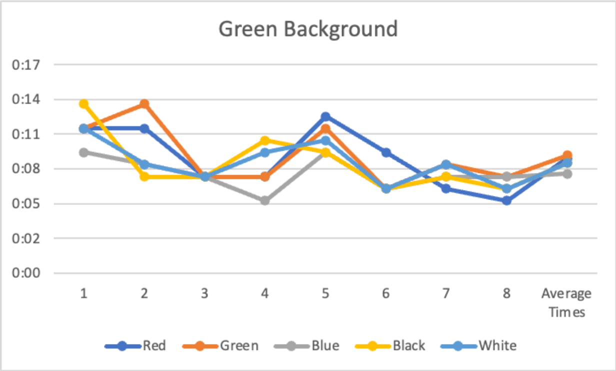

Figure 6: Average time users took on the different crosshair colors for the green background

6. Future work

The research team believes that the findings of this study hold practical implications for domains where markers are employed, such as shooting sports, video games, and military training. In precision shooting disciplines, such as shooting sports, the color of the crosshair has been found to have an impact on the accuracy of the shot. In certain circumstances, it may be necessary for shooters to modify the color of their crosshair in order to enhance their accuracy when participating in competitions that feature a variety of backgrounds. The aforementioned statement holds true in the context of military and law enforcement training, wherein soldiers and officers are required to expeditiously acclimatize themselves to varying circumstances and objectives. The findings of this research can be utilized to enhance the video game design, thereby enhancing the user experience. Game designers have the option to select crosshair colors by taking into consideration the colors of the background and the objective, during the game development process. In addition, players are afforded the opportunity to modify the color of the crosshair to align with their personal preferences or the contextual backdrop of the game. Furthermore, the findings of this investigation may be applicable in scenarios involving human-machine interaction, such as those encountered in flight simulators or unmanned aerial vehicles. The utilization of crosshairs is particularly crucial for pilots to achieve accurate targeting in such circumstances. The selection of an appropriate crosshair color has the potential to enhance performance and minimize errors. The implications of this research may have significant impacts on the defense industry. The utilization of crosshairs is imperative for precise targeting and effective engagement of adversary forces in military operations. It is imperative to comprehend the impact of diverse crosshair colors on individuals' perception and conduct. The findings of this investigation have the potential to inform the development of a chromatic reticle mechanism that adapts to both the contextual environment and the target object. An instance of a crosshair color that exhibits optimal performance on a white background may not demonstrate the same level of efficacy on a green background. The implementation of a crosshair color alteration system based on the surrounding environment could potentially enhance the precision and efficacy of soldiers. The findings of the study can be utilized to enhance the development of military exercise and training regimens. The incorporation of crosshair color perception in training programs can enhance their realism, thereby simulating real-life scenarios. Enhanced training can potentially result in improved performance of soldiers during field operations.

7. Conclusion

The current study has presented empirical support for the impact of different crosshair colors on individuals' ability to detect targets amidst varying backgrounds. Therefore, one can deduce that the color of the crosshair is a significant factor in pinpointing the target. The findings indicate that the choice of crosshair color can significantly affect the accuracy and speed of target acquisition. The study has noteworthy pragmatic ramifications for diverse fields, such as marksmanship, electronic gaming, armed forces instruction, and safeguarding purposes. The results of this study could potentially be applied to improve the design of video games, training programs, and military operations by identifying the most effective crosshair colors that are best suited for specific backgrounds and targets. The potential enhancement of precision and efficacy in military operations can be achieved through the implementation of a chromatic crosshair mechanism that is adaptable to the environment. This research highlights the importance of considering the hue of the crosshair when designing visual aids for tasks related to targeting and aiming.

8. Demo

The group demo can be accessed from this link.

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