Color Blindness in the Digital Gaming Landscape: Addressing Critical Issues and Research Gaps

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Abstract: Color blindness is a condition that affects a significant portion of the population, particularly men. It is characterized by difficulty perceiving colors in the same way as people with normal color vision, which can result in confusion when distinguishing between different colors. This can impact various aspects of life, including playing digital games. In computer games, colors are often used to convey important information, such as distinguishing enemies from allies or indicating objectives. A person with color blindness may have difficulty identifying these visual cues, which can make the game less enjoyable and even affect their ability to play the game. Previous research has been conducted on accessiblity but very few of these studies have focused on the intersection of color blindness and digital games. The aim of this study is to examine the relationship between color blindness and game design through a comprehensive literature review, identifying key findings and highlighting any missing components in the existing research. To accomplish this, the sources were classified according to their focus, method, and findings. From examining all of the resources found, the studies in the intersection between color blindness and game design that reviewed, organized into various subject headings for further analysis and understanding. It was explored that the researches organized under certain four main topics as follows: (1) defining guidelines to provide better game experience for color blind individuals, (2) offering alternative methods for detecting color blindness; and (3) examining technologies developed to improve the visual experience of color blind individuals and (4) examining color blindness on gaming performance. Additionally, the majority of the reviewed studies focus on discussing digital games in terms of accessibility, while some studies suggest utilizing games as a testing method and educational tool for individuals with accessibility issues, effectively turning challenges into advantages. On the other hand, they also explore the potential of games in solving problems related to accessibility in gaming. However, there is still many issues to be explored in terms of understanding how color blindness affects the experience of games. There is a research gap in exploring whether color blind individuals experience physical and sensory differences in perceiving digital game visuals, as no study has been conducted to address this aspect. It may address critical issues in understanding the color blindness experience from the perspective of perception and senses of this disadvantaged group.

Keywords: *V*isual impairments, Color blindness**,** Color vision deficiency, Accessibility in games, Game interactions, Gaming experience and game art/visualization

1. Introduction

The human body has a complex response to color and visual perception. Factors such as culture, personal experience, and individual differences can all play a role in how we perceive and respond to color. Our brains interpret the colors and visual stimuli we encounter in our environment, and this can influence our behaviour, emotions, and overall perception of the world around us. However, this does not apply to all individuals. Color blindness can affect the way that individuals with this condition perceive and respond to color and visual stimuli in digital world.

In the digital world, color emerges as a fundamental and compelling element that holds immense significance, particularly within the realm of digital game art. As technology continues to shape our interactive experiences and entertainment, the use of color has become a pivotal aspect of digital design. Within this dynamic landscape, colors play diverse and multifaceted roles, encompassing aesthetics, functionality, psychology, and storytelling. From the vivid visuals of digital games to the immersive virtual environments, color serves as a powerful tool that influences user perception, emotional engagement, and gameplay mechanics.

In the context of digital games, individuals with color blindness may have difficulty perceiving certain colors or color combinations, which can affect their ability to accurately interpret and interact with the game world. This can be particularly challenging in games that rely heavily on the use of color to convey important information or to differentiate between different game elements.

This article explores the critical importance of color in the digital realm, particularly from the perspective of color-blind individuals with a specific focus on digital game design. It aims to unravel the impact of color on player experience, visual communication, and the creation of memorable and captivating virtual worlds through

a research study. The following section presents an overview of color blindness and its testing methods to serve as a point of reference for the topics to be addressed in the literature research section and to provide essential background information on the subject matter. In the subsequent section, we conducted a comprehensive review and synthesis of existing studies conducted at the intersection of color blindness and game visualization. Lastly, we summarize the key findings and implications derived from these studies in the fourth and final section.

2. Color Blindness: Conceptual and Theoretical Background

2.1 Understanding Color Blindness

Color blindness, also called color vision deficiency, is a condition where people have difficulty seeing colors in the same way as people with normal color vision. This can affect their ability to distinguish between different colors or to see colors at all. Flueck (2006) argues that ‘’The first scientific paper about color blindness was written by John Dalton in 1793 entitled “Extraordinary facts relating to the vision of color “. Dalton himself was red- green colorblind and as a scientist he took interest in this topic. He claimed that a colored liquid inside the eyeball is the source for a different color perception. This was proved wrong only after his death, when his eyes were examined and no such liquid was found.’’(Flueck, 2006).

Color perception in the human eye is built up by three different types of cones. Each type is sensitive to a certain wavelength of light (red, green, and blue) and every perceived color is therefore a mixture of stimuli of those three cone types. The type of affected cones also has a big impact on your color vision deficiency. As there are three different types of color receptors, there are also three different main forms: red (protan), green (deutan), and blue (tritan) disorders. As red and green deficiency result in quite comparable color vision problems, they are often taken together and known as red-green color blindness. Futagbi, G et. al. (2011) categorized the color blindness as following:

- Monochromatism: Either no cones available or just one type of them.
- Dichromatism: Only two different cone types. Third one is missing completely.
- Anomalous trichromatism: All three types but with shifted peaks of sensitivity for one of them, which results in a smaller color spectrum.
- Dichromats and anomalous trichromats exist again in three different types according to the missing cone or in the latter case of malfunctioning.
- Tritanopia/Tritanomaly: Missing/malfunctioning S-cone (blue).
- Deuteranopia/Deuteranomaly: Missing/malfunctioning M-cone (green).
- Protanopia/Protanomaly: Missing/malfunctioning L-cone (red).

Table 1: Different forms of color deficiency (Ismail, 2015)

Type	Denomination	Prevalence %	
		Men	Women
Monochomacy	Achromatopsia	0.00003	
Dichromacy	Protanopia	1.01	0.02
	Deuteranopia	1.27	0.01
	Tritanopia	0.0001	
Anomalous Trichromacy	Protanomaly	1.08	0.03
	Deuteranomaly	4.63	0.36
	Tritanomaly	0.0002	

Color blindness is a common condition, affecting about 1 in 12 men and 1 in 200 women. Most of colorblind people are male, because the most common form called red-green color blindness is encoded on the X-chromosome and therefore sex-linked. As red-green color blindness is inherited from a mother to her son, a father never passes this type of color blindness on to his male children. Moreover, it is typically inherited and is not usually a sign of any underlying medical condition. (Alamoudi, N. B et. al. 2021)

The term red-green color blindness is often used but actually not quite correct. Every type of color vision deficiency affects the whole color spectrum and therefore cannot be reduced to just certain colors. Another

common misconception about colour-blindness is that color blind people are unable to see certain colors or some colors appear grey for them. Colorblind people are actually unable to distinguish certain colors. (Tanuwidjaja, E et. al., 2014)

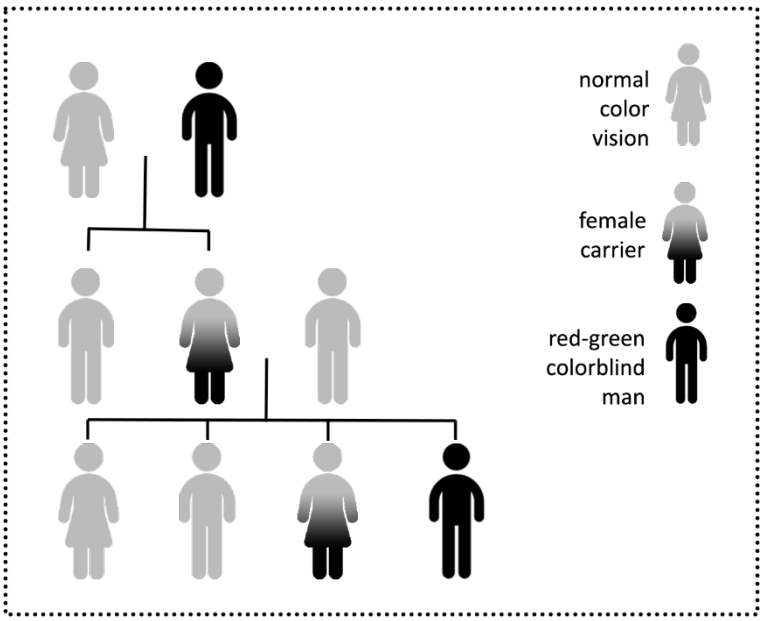

Figure 1: Red-green color blindness inheritance pattern (Flueck, 2006)

2.2 Color Blindness Tests

There are different possibilities to test color vision and it is not possible to accurately count the number of tests available because there are too many tests. Flueck, (2006) mentions that how well-known tests work.

Anomaloscope: It provides the most accurate possibility to test the severity of color blindness and distinguish between dichromats and anomalous trichromats.

Pseudoisochromatic plates: They are the most famous type of color blindness test. Most people know them under the name Ishihara plates test. These plates consist of a series of patterns or figures made up of different colors and shapes. The person being tested is asked to identify the pattern or figure that is hidden within the colors. For people with normal color vision, the hidden pattern or figure is typically easy to see.

Arrangement tests: Also known as ordering tests, are used to test for color blindness. These tests typically involve arranging a set of colored chips or blocks in a particular order based on their color. The person being tested is asked to arrange the chips or blocks in a way that demonstrates their understanding of the colors and the relationships between them.

Lantern tests: They also known as light signal tests, that are used to test for color blindness. These tests typically involve using a special lantern or light signal device that displays different colors and patterns. The person being tested is asked to identify the colors and patterns being displayed. Some commonly used lantern tests include the City University Color Vision Test and the Farnsworth Lantern Test.

There is no single "best" color vision test, as different tests may be more suitable for different situations and individuals. Different color vision tests are designed to test for different types and levels of color blindness, and some may be more effective at detecting certain types of color vision deficiency than others.

3. Previous Studies at the Intersection of Color Blindness and Game Design

This research focuses on exploring the relationship between color blindness and game visualization. During the initial literature search, it was observed that there is a scarcity of studies specifically dedicated to game visualization. Consequently, additional keywords such as "digital visualization" and "user experience" were incorporated in the literature research phase to expand the scope of investigation. Through this iterative process, a final set of keywords was identified to refine the research area, encompassing subjects related to color blindness and game technology, including visual impairments, color vision deficiency, accessibility in games, game interactions, gaming experience, and game art/visualization. A comprehensive literature review

was conducted, involving the exploration of three distinct sources (Scopus, Web of Science, ACM) using various combinations of the identified keywords. As a result, a substantial number of research texts, approximately a hundred, were found to be relevant to the identified subjects. After a preliminary examination of these sources, it was determined that several studies delved into areas outside the scope of our research, such as health and education. Ultimately, fifteen sources were deemed closely aligned with the subject and offered valuable insights for the literature search. Among these, four sources were excluded from the research area due to their detailed focus on engineering and numerical calculations. The remaining sources were thoroughly scrutinized based on the subjects they explored, the methodologies employed, and the outcomes they presented. Given the limited number of studies in the intersection area, the literature search was not confined to a specific type of color blindness. Consequently, a diverse range of articles was considered in the subsequent analysis. The study aims to analyze eleven of these relevant articles in the continuation, contributing to the understanding of color blindness in the context of game design and fostering new perspectives in this evolving field. (table 2)

Table 2: Literature review

N	Article Name	Year	Keywords	Objectives
1	DoDo game, a color vision deficiency screening test for young children	2014	Children game; Color deficiency test; Digital game	Offering an alternative way to detect color blindness in early ages
2	Perspectives on Accessibility in Digital Games	2018	Accessibility; Educational serious games; Serious game design; Customisation; Choices; Alternatives	Arguing the importance of educational games in terms of supporting disabled children and teachers
3	Flying colors: Using color blindness simulations in the development of accessible	2021	Accessibility, Color Blindness, Games, Mobile	Examining the usage of digital simulations to increase accessibility and awareness during the development of mobile games.
4	Chroma: a wearable augmented-reality solution for color blindness	2014	Augmented-reality; Glass; Wearables; Color blindness	Focusing on using AR glasses to improve the vision of colorblind individuals.
5	Exploring the Impact of Colour-Blindness on Computer Game Performance	2018	Accessibility; Colour Blind; Online Games; Performance	Examining the effects of color blindness on casual computer gaming performance and experience
6	Design proto-patterns to improve the interaction in video games of people with color blindness	2019	Video games, Visual Impairment and Color Blindness, Accessibility Barriers, Design Guides and Patterns.	Addressing the challenges faced by individuals with color blindness when playing video games and provide recommendations.
7	The Windows 10's Color Filter Feature as an Aid for Color Blind People in the Use of Websites	2021	Accessibility, Color Blind, Color Vision Deficiency, User Experiences, Windows Color Filter	Discussing whether the Windows 10 color blindness filter is efficient in terms of user experience.
8	See a Different World: Interactive Storytelling for Children to Raise Awareness of Color Blindness	2015	Color blindness--Interactive multimedia Design; Visual communication; Computer games Design	Providing an educational tool that is both engaging and inclusive for all children.
9	The Whose View of Hue?: Disability adaptability for color blindness in the digital game Hue	2018	Game Design, Accessibility, Universal Design, Color Blindness, Hue.	Discussing Hoffman's design process and proposing a framework for accessible game design
10	The composition of visual texture design on surface for color vision deficiency (CVD)	2019	Color vision,Color Vision Deficiency (CVD),Texture composition,Psychophysics, Color threshold	Searching for how different colors, sizes, and distances of textures could help people with color vision deficiency
11	Prototyping "Color in Life" EduGame for Dichromatic Color Blind Awareness	2021	Color blind, Educational game,Gaming experience mobile game	Increasing players' knowledge about color blindness with a game specifically designed for dichromatic color blindness.

Old color blindness tests may need alternatives due to potential limitations in accuracy, accessibility, cultural applicability, specificity, and sensitivity. Embracing alternative tests can leverage advancements in technology, address these limitations, and offer a more effective and user-friendly approach to identifying color vision deficiencies. For these reasons, some studies propose alternatives to the traditional testing methods mentioned in the previous sections. One prominent study (1) conducted by Linh-Chi et. al. (2016) offers a game that incorporates engaging elements, making it suitable for early-age screening. The DoDo game consists of four sub-games targeting different types of color deficiencies, including Yellow-Blue and Red-Green color blindness, total color blindness, and distinguishing between deuteranopia and protanopia. By identifying color vision deficiencies at a young age, potential challenges in learning and academic performance related to color-dependent tasks can be addressed promptly. The interactive and game-like nature of the DoDo game makes it a more engaging and less intimidating option for young children compared to traditional color screening methods that may rely heavily on cognitive or verbal abilities. The DoDo game's effectiveness in identifying Red-Green color deficiencies, comparable to established screening tests, implies its potential as a reliable alternative.

However, it is important to note that the study was conducted with a relatively small sample size of 28 children in Singapore. Further research with a more extensive and diverse participant pool would be beneficial to validate the game's effectiveness in various populations. alternative.

Some researchers support that AR technology is very useful in game development and in increasing the game experience such as Pinheiro et al. (2021). Study(**3**) highlights the significance of integrating chromatic accessibility into the design process by using simulations at various stages of game development. The research aims to address three key questions: first, whether augmented reality simulations are beneficial for considering chromatic accessibility during the design phase; second, if there are specific accessibility problems that only a particular simulation type can detect; and third, whether using augmented reality simulations provides advantages over screen simulations. Study show that early identification of accessibility issues ensures a more inclusive gaming experience for color-blind individuals and enhances the overall user experience for all players. The experiment involved utilizing simulations on both desktop and augmented reality platforms during the development of an actual mobile game, comparing the use of augmented reality simulations with filters applied to the screen. This comparison between augmented reality and screen simulations offers valuable insights, empowering developers with options that align with their specific needs and resources. Moreover, the study highlights the necessity of using a mix of simulation methods to fully evaluate and address accessibility issues effectively. An additional study(**4**) executed by Tanuwidjaja, et. al. (2014) reinforces this matter by exploring the use of scrutiny glasses to enhance the user experience. They focused on using AR glasses to improve the vision of colorblind individuals. To address this issue, a wearable augmented-reality system known as Chroma was developed based on Google Glass, allowing users to view a filtered image of their surroundings in real-time. Chroma's objective is to assist colorblind users in distinguishing colors they typically struggle to see, thereby providing them with access to different color dimensions and enhancing their everyday activities. To provide that it adapts the scene-view based on the type of color blindness and includes algorithms for color saliency. The research group conducted interviews with 23 people with color blindness and implemented four modes to assist them in distinguishing colors they typically cannot see. While AR technologies still has limitations, initial tests demonstrated promising results, indicating that colorblind individuals using the wearable AR device could improve their color recognition abilities. The implementation of AR glasses holds significant potential to enhance the daily lives of colorblind users by facilitating color perception and aiding them in tasks where color identification is crucial.

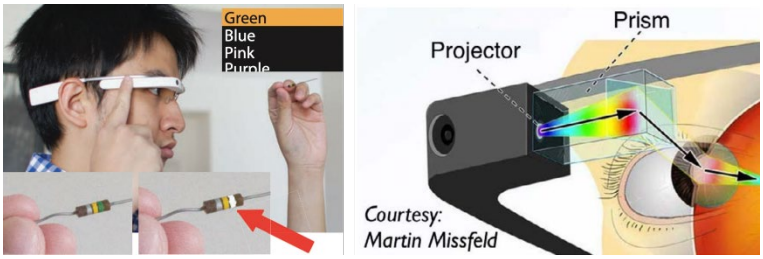

Figure 2: Colorblind person wearing Chroma glasses (Tanuwidjaja, et. al, 2014)

Hauge et al.'s (2018) article(**2**), brings to light the crucial issue of accessibility in educational games, especially for students and teachers with impairments. Researchers explore strategies to enhance the accessibility of educational games, with a particular focus on addressing visual impairments in games used for STEM education. It underscores the significance of making educational games more inclusive to support disabled individuals and foster equitable learning experiences. The proposed solutions, including enhancing visual accessibility and incorporating text-to-speech input, address significant barriers faced by students and teachers with impairments. The introduction of the Accessabar platform as a potential solution is an intriguing aspect of the study. Although the specific details of the platform are not provided in the review, the concept of a comprehensive tool to address multiple accessibility needs in digital games is highly promising. The Accessabar platform seems to offer a versatile and unified solution to support various impairments.

Napoli and Chiasson (2018) conducted a comprehensive study(**5**) which diligently examined the effects of color blindness on casual computer gaming performance and overall user experience. Through online puzzle game experiments conducted in both regular and simulated color-blind environments, the researchers found that while objective measures did not demonstrate a significant decline in gaming performance due to color blindness, the participants' subjective perception of the game's difficulty was influenced. This discrepancy emphasizes the need for further exploration of the influence of color vision deficiency on gaming experiences.

In a separate study(**7**), Paiva et al. (2021) proposed meticulously investigating the effectiveness of the Windows 10 color blindness filter in enhancing user experience on websites. Their findings demonstrated notable improvement across various scenarios, with varying degrees of effectiveness based on the type of color blindness. The study's results demonstrated improvement in user experience for most scenarios when using the color filter. However, the degree of improvement varied depending on the type of color blindness. The protan type color blind group saw the most significant improvement, particularly in situations where websites required user actions. On the other hand, the deutan type color blind group experienced the least improvement, but interestingly, they rated the overall experience the highest. These studies collectively emphasize the critical importance of considering color vision deficiency in design and accessibility guidelines to ensure inclusive and enhanced user experiences in gaming and website usage.

Awareness of color blindness in early ages is crucial because it allows for timely identification, enabling children with color vision deficiencies to receive appropriate support and accommodations in their educational and daily activities. Both the articles by Ivan et al. (2021) and Dan (2015) center around the objective of raising awareness and promoting understanding of color blindness. Ivan et al.'s study(**11**) focuses on the development of an educational video game called "Color in Life," specifically designed for individuals with dichromatic color vision deficiency. The game utilizes tailored graphics and gameplay to provide an interactive learning experience about color blindness. The positive findings, indicating an increase in players' knowledge and awareness of dichromatic color vision deficiency after playing the game, validate the effectiveness of the tailored game design. Moreover, the game's accessibility and appeal to both individuals with and without color vision deficiency highlight its potential to be an inclusive and informative educational tool for a broader audience. On the other hand, Dan's article(**8**) delves into the realm of interactive storytelling, presenting an alternative approach to educating children about color blindness. Study addresses the limited availability of interactive applications specifically designed for children with disabilities, with a particular focus on children with color blindness. It aims to fill this gap by developing an interactive visual storytelling application called "See a Different World" that serves as an engaging and inclusive educational tool for elementary school-aged children. The "See a Different World" interactive application incorporates unique characters, colorful elements, and engaging reading and playing activities to raise awareness among young audiences. The application incorporates reading and playing activities to facilitate learning about color blindness and includes a short color-blind test to help children understand their own color perception. both articles recognize the potential of digital technology, particularly digital game art and interactive storytelling, as effective mediums to convey information and promote awareness about color blindness.

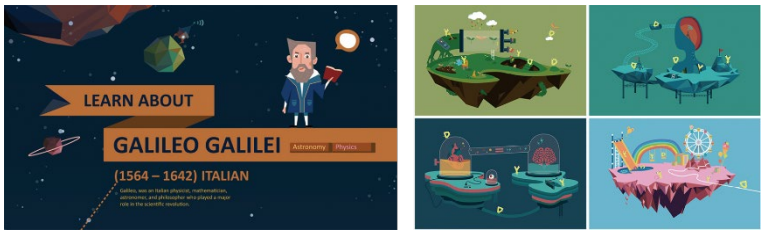

Figure 3: Design ideation (Dan, 2015)

In the study(**6**) conducted by Josefa and Nuria (2019), the researchers provided a thorough analysis of the challenges faced by individuals with color blindness in the context of video games, which aligns with the study(**9**) by Plothe (2018). Both studies focus on addressing color vision deficiency in game art to enhance the interaction and gameplay experience for individuals with color blindness. Josefa and Nuria proposed 12 design prototype patterns that offer practical and effective recommendations, such as setting alternative colors for better perception by color blind individuals, associating labels and shapes with characters and interactive elements, and enabling customizable visual effects. Similarly, Plothe's research on "Hue" showcases how accessibility for colorblind players was carefully considered in the design process, leading to the incorporation of built-in and customizable modes using patterns instead of colors to ensure inclusivity in gaming. Article delves into the journey of transforming the digital game Hue from exclusion to inclusion for colorblind players. The interview-based case study with the game's creator, sheds light on the design process that led to the implementation of built-in and customizable modes, making the game more accessible for colorblind individuals. Together, these studies underscore the crucial importance of adopting universal design principles and inclusive approaches to create video games that cater to the needs of individuals with color blindness.

Tseng and Cheng's (2019) study(**10)** provides essential insights into the realm of visual accessibility, addressing the challenges faced by individuals with CVD. The research delves into crucial design elements like colors, sizes, and distances of textures, aiming to enhance color perception while preserving visual appeal for normal vision individuals. The incorporation of specific parameters, such as RGB color 234, 0, 21, element size 2.50, and distance 2.5', underscores the rigorous and thoughtful approach taken in identifying effective solutions. The study's recognition of the potential influence of material and environmental factors on the proposed design elements reflects the researchers' commitment to real-world applicability. This research not only advances accessible design practices but also fosters a more inclusive digital landscape, promoting meaningful engagement with visual content for all users.

4. Discussion and Conclusion

In the previous section, it has been determined through research that there have been a significant number of studies conducted on the topic of color blindness and its impact on game design. A total of 11 selected sources have been analysed in terms of their methodologies, content and findings. Based on the reviews, it has been observed that three methodologies are predominantly used in research: human experiments, pre-tests, and interviews. Researchers used pretests to establish reliability and validity, provide baseline measurements, identify outliers, monitor participants' progress, and address ethical considerations before the main study. Additionally, it is worth noting that many studies in this field have utilized a combination of these methodologies to support their research process. For instance, the majority of the studies that conducted measurements on the experimental group first utilized traditional color blindness tests to compare the results and draw inferences by contrasting this data with their own experimental setups.

Thorough analysis and interpretation of the research outcomes, the findings of these studies were grouped into two categories: numerical data and verbal comments. Studies 2, 6, 7, and 9 utilized verbal assessments rather than numeric data in presenting their findings. In contrast, the 10th study employed a numerical data-driven approach to represent its research outcomes, reflecting a different methodological approach. While only a minority of the studies focused solely on addressing the proposed theoretical framework, a significant proportion aimed to serve as references for future research by generating novel discussions based on hypotheses supported by numerical data. This observation indicates a growing trend within the research domain, emphasizing the importance of empirical evidence and quantitative analysis in advancing the understanding of the subject matter.

Table 3: Classification of articles

<table>
<tr><th>Content</th><th>Methodolgy</th><th>Findings</th></tr>
<tr><td>Examining technologies:
3, 4, 7,</td><td rowspan="2">Human experiment:
11, 10, 8, 7, 5, 4, 3, 1</td><td rowspan="2">Numerical analyses:
1, 3, 4, 5, 8, 10, 11</td></tr>
<tr><td>Defining guidelines to provide better game experience:
2, 6, 9, 10,</td></tr>
<tr><td>Offering alternative methods for detecting color blindness:
1, 8, 11</td><td rowspan="2">Applying a pretest/form:
7, 8, 11, 5, 1, 4</td><td rowspan="2">Verbal analyses:
1, 2, 3, 4, 5, 6, 7, 8, 9, 11</td></tr>
<tr><td>Examining impacts of color blindness on user performance:
5, 7,8, 11</td><td>Interviews:
9</td></tr>
</table>

The studies in the intersection between color blindness and game design mostly focused on single subjects, except for one that explored multiple subjects simultaneously. This highlights the diversity in methodologies and approaches used within the academic landscape to address research questions and explore various aspects of the chosen subject matter. The researches were organized into various subject headings for further analysis of their content, covering topics such as defining guidelines for better game experience for color blind individuals, examining the impacts of color blindness on user performance, offering alternative methods for detecting color blindness, and exploring technologies to improve the visual experience for color blind individuals. One of the four main research areas in this study is the improvement of color-blind individuals' gaming experience with the

support of advancing technology. As mentioned earlier, both Study 3 and Study 4 have explained through tests that technology contributes positively to color-blind players' gaming experience. Another area that many studies have focused on is the modernization of traditional testing methods through digital games, making them more appealing and encouraging early diagnosis for individuals of all age groups. Studies 1, 8, and 11 all highlight the importance of digital games in detecting color blindness, especially at an early age. Unlike other research areas that primarily discuss the accessibility aspect of games for color-blind individuals, this research topic introduces a fresh perspective by proposing that games can be utilized as a method for detecting color blindness, offering a novel approach to the subject. Moreover, some studies measure color-blind individuals' digital game experiences and performance, while others offer recommendations to mitigate the identified negative implications. These reference-worthy recommendations can be highly beneficial for game developers.

One particularly noteworthy finding comes from Study 5, where the evaluation indicates that color blindness does not have a direct impact on performance, but participants' emotional perceptions are affected. However, it was revealed that no study was included which questioned whether color blindness causes differences in emotional and physical responses among individuals with different visual abilities (color blind individuals and individuals with normal visual ability). Based on the lack of research on the subject, carrying out a future study that will involve a group of people with different ages and vision abilities completing emotional analysis tests after interacting with games in both a normal and simulated color-blind environment can be beneficial to fill the gap in the academic field. Physical(such as heart rhythm, mimics) and emotional responses(such as happiness, sadness) will be measured to determine if color blindness causes differences about reactions in players' experiences.

To sum up, in recent years, there has been a growing awareness of the importance of considering accessibility for players with color blindness in the design of video games. Researchers have explored various techniques for improving the visibility of game elements for colorblind players, including the use of patterns and texture, as well as alternative color schemes and customizable settings. These efforts have helped to make games more inclusive and accessible to a wider range of players. However, there is still much work to be done in this area, and further research is needed to fully understand the impact of color blindness on gameplay experience and to develop effective design strategies for supporting players with this disability. Overall, it is clear that game designers and researchers must continue to prioritize the inclusion of players with color blindness in the design and development process in order to create truly accessible and enjoyable gaming experiences for all.

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