Exploring the Influences of Colour Scheme on User Response Time in Virtual Reality Games

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Abstract
In recent years, with the rapid development of the virtual reality (VR) industry, the number of VR game- users is increasing. Colour is an integral part of visual presentation in VR games. Research on the influence of colour schemes on user response time was conducted on LCD screens, websites, and smartphones. There are differences between VR and the platforms in terms of equipment, immersion, field of view and dimension, and user response time is one of the critical factors in user experience. This article will study how colour schemes influence user response time on user experience. Additionally, research on the influence of colour on user response times is limited to specific colour combinations, such as a yellow background, white foreground, or comparisons of the same colour and multiple colours. This research, using an experimental method, explores the influence of colour on user response time on the Oculus Quest 2 virtual device platform. It can be provided to VR game developers to make the design more solid. Understanding the effectiveness of interactions can provide adequate data for future research on improving user experience.

Keywords: Colour Scheme, User Response Time, Virtual Reality Games, User Experience

1. Introduction

Virtual Reality (VR) is an immersive computer modelling and simulation technology that allows users to immerse themselves in a computer-generated environment and attempt things that are difficult to do in real life (Kwok et al., 2019). In the beginning, the design of colour schemes was mainly focused on printed materials. However, with the continuous advancement of technology, colour scheme design has gradually transitioned to traditional display platforms (LCD, computers, smartphones). For this reason, some researchers have investigated the relationship between traditional screen colours (Siek, et. al, 2023) and user response times. Notable examples include LCDs(Huang & Chiu, 2007), computers (Kimmons, 2020), and smartphone displays (Liu et al., 2021). VR colours are more immersive and easier to focus on than traditional displays. This can increase enthusiasm and motivation for learning and reduce user response time. A study by Shu et al. compared the effects of VR and computer screen immersion using an earthquake educational VR system.

This study found that VR users had a stronger sense of spatial presence and immersion than their desktop displays (Shu et al., 2019). Consequently, participants may pay more attention to the colour scheme, which affects the users' response times. On the other hand, colours in VR can also be uncomfortable for users due to Variance Adjustment Conflict (VAC), VAC occurs when the brain recognises a discrepancy between the perceived distance of a 3D virtual object and the required focusing distance of the eyes (Kramida, 2016), and this unpleasant effect also affects the user's response time. In recent years, with the rapid development of the VR industry, the number of VR game users has also increased. The VR industry has evolved over the past few decades based on the integration of previous research into interactive 3D graphics and user interfaces. Currently, the expansion of games to VR has begun. Similar to other computer games, VR gaming applications typically include colour information and commands in the interface that users must accept and respond to. VR games have the potential to influence a wider audience (Zyda, 2005). Colour schemes are an integral element of all VR applications, so their impact on user experience is interesting. Surprisingly, knowledge about the effects of colour in virtual environments is limited (Coursaris & van Osch, 2016). Meanwhile, researchers have shown a growing interest in understanding user experience in VR games (Radianti et al., 2020). Among the key aspects of user experience, user response time is particularly prominent (J. Ahn et al., 2017). Given that VR is a relatively new technology, it inherently has the novelty and interesting to engage users. As a result, users tend to exhibit a higher intrinsic motivation to explore and understand VR (Jing et al., 2023), which positively impacts the understanding of user response time.

Previous studies on colour schemes and user response time have focused on specific colour combinations and different platforms. For example, in LCD screens, Huang et al. conducted a study to evaluate the effect of two specific colour combinations on user response time. However, user interfaces usually consist of essential components: interactive objects (button colours), structured graphical objects (background and geometry colours), and structured text objects (font colours) (Linton et al., 1989). The analysis of the effect of icons and background colours on user response time alone cannot cover all the essential components of the user interface, which leads to its insufficient application in the actual VR colour scheme design process. Similarly, on smartphones, Liu's study compared the effects of same-coloured and multi-coloured icons on user response times but only examined icon colour and ignoring the background and font colour. The omission of other essential user interface components again limits the applicability of the study to VR colour scheme design.

Differences between traditional screens and VR environments can impact the colour scheme of user response times. In addition, the impact of colour scheme on user response time in traditional displays cannot cover all basic user interface components. Therefore, further research is needed to investigate the effect of colour scheme on user response time in VR. Before research study the impact of colour schemes on user response time, researchers need to discover the colour scheme of the latest VR applications to do better research. Based on user-centred design principles, the colour schemes of virtual applications will be discovered from the user's perspective. Research on the impact of colour schemes on user response times is limited, so a specific colour scheme alone is not sufficient to cover all components of a VR user interface. Furthermore, relying solely on existing research and data proved insufficient to convince product managers to adopt a specific colour scheme during the design phase. This deficiency hinders the development of software products with colour schemes that encompass all components of the user interface as consideration of colour schemes and user response times in critical components of the user interface is currently incomplete. Therefore, it is necessary to understand the impact of VR colour schemes on user response times. Oculus Quest is a phenomenal VR device with many VR games for studying the effect of colour schemes on user response times, providing researchers with plenty of suitable applications. Therefore, this study uses a VR game on the Oculus Quest platform to study the impact of colour schemes on users' response times.

Based on the above, the research objectives of this study are to examine the colour schemes used in contemporary VR games from the user's perspective and to analyse the impact of colour schemes on user response times in VR games.

2. Literature Review

2.1 Virtual Reality Games

VR game is a game played in a VR environment. Unlike traditional video games that are played on a screen, VR games are experienced through a headset or glasses, allowing the player to see and interact with his three-dimensional virtual world. VR games are video games played on VR hardware(Pallavicini et al., 2019). Most VR games rely on the player immersion, usually via a head-mounted display unit or a device with a stereoscopic display and one or more controllers (Liszio & Masuch, 2016). In other words, VR games allow you to experience and interact with the three-dimensional environment while playing the game. VR games work by utilising a combination of specialised hardware and software. The hardware usually consists of a VR headset worn by the player, which includes a screen that displays the game world in 3D and motion tracking controllers that allow the player to interact with the virtual world (Kim et al., 2020). VR gaming software is designed to utilise specialised hardware to create a highly immersive experience, which includes realistic 3D environments, advanced interactions, and audio that responds to the player's movements and actions (Pallavicini et al., 2019).

2.1.1 User Interface in Virtual Reality

Yue's research focuses on user interface design in VR. It is proposed that one of his strategies for constructing 3D interfaces is to create a natural and harmonious interaction between humans and machines. Yue also discusses the importance of his 3D user interface when interacting in virtual space. This includes designing intuitive and user-friendly interfaces that allow users to interact with virtual objects, environments, or information in a natural and

seamless manner. This can be achieved through well-designed input modes, sensory feedback, and careful consideration of the user experience (Yue, 2021).

In a study conducted by Coomans and Timmermans, they categorised various types of VR User Interfaces (VRUI). Specifically, VRUIs are categorised into two main types based on the underlying physical media. One category consists of output media types that include graphic, acoustic, and haptic components, and the other category includes kinematic, acoustic, and graphic components. This study systematically categorises VR user interfaces by thoroughly examining their unique features, functionality, and potential applications. However, it is worth noting that there is no mention of an in-depth study of the classification of VR user interfaces in terms of the visual composition of the interface (Coomans & Timmermans, 1997).

2.2 User Interface Components

From the perspective of designing user interfaces, Linton et al. describe a user interface toolkit called InterViews developed at Stanford University. The toolkit provides rich combination mechanisms and a variety of predefined objects that can be combined to create software user interfaces. InterViews supports a combination of his three object classes: interactive objects, structured graphic objects, and structured text objects. Interactive objects are user interface components that allow users to interact with the application, such as scroll bars and menus. Structured graphic objects are graphic elements such as circles, polygons, and patterns. Structured text pairs are text elements such as words and whitespace, that can be combined to create complex layouts (Linton et al., 1989).

2.3 Virtual Reality Menus

Menus are part of the VR user interface. Research has shown that using virtual menus is an effective way to interact with virtual environments and is commonly used in many scenarios (Jacoby & Ellis, 1992). Wall's research examines research methods for developing VR visualisations and discusses the challenges of menu design for VR interfaces. The study found that users prefer menus that are easy to navigate and have clear visual cues. Wall also emphasised the importance of clear visual cues to the menu user experience (Wall, 2021).

2.4 Virtual Reality Game Users

Data shows that global VR gaming revenues have reached US$22.9 billion, with over 171 million VR users worldwide(Christo, 2021). The age distribution of VR game players is relatively wide, but male users tend to be younger (18-34 years old), while female users are more evenly distributed. According to the data provided by Mainland China Data Network, by the end of 2020, the gender ratio of VR game players in China will be 67.7% male and 32.3% female. According to the "China VR User Behaviour Research Report," China's VR users are mainly aged 18-34, accounting for 62.5%. The 25-29-year-old group has the highest utilisation rate, accounting for 28.6%. The next largest group was 30-34 years old, accounting for 22.6%. Among the young people, the utilisation rate for those aged 18-24 was also high at 11.3%.

2.5 HSB

Alternative names for HSB include HSV (value), HSI (intensity), and HSL (light). In digital design, Khairunniza-Bejo and Kamarudin's research focuses on the main factors of human colour perception, HSB, i.e., namely: Hue, Saturation, and Brightness. Hue is a property of a colour that describes its pure colour, while saturation measures the amount of white in a pure colour. The intensity of a colour image corresponds to the grey level (Khairunniza-Bejo & Kamarudin, 2011).

A study by Lyu et al. investigated the impacts of colour design of user interfaces on all age groups. The study compared the saturation and tonal intensity of child and adult user interfaces, respectively. This study found that different types of application interfaces use different colour frequencies in terms of hue. Educational application interfaces use cool colours, such as blue, while gaming application interfaces use warm colours such as red and orange. When it comes to saturation, the adult user interface is more saturated. In terms of brightness, adult application interfaces typically use desaturated colours (Lyu et al., 2022).

2.6 User Response Time

Miller's study discussed the definition of response time. According to Miller, different human goals and behaviours require different acceptable or actual response times (Miller, 1968). In Huang and Chiu's study, the relationship between specific colour schemes on LCD screens and users' visual search time was investigated (Huang & Chiu, 2007). Hoxmeier and DiCesare discussed the effect of system response time on user satisfaction, showing that satisfaction decreased with increasing system response time (Hoxmeier & DiCesare, 2000). Staggers and Kobus compared two text-based and prototype graphical interfaces to understand the differences in response time (RT), errors, and satisfaction when nurses perform computational tasks (Staggers & Kobus, 2000). The response time in their study indicates that two elements, visual search time and system response time, are the user response time.

3. Research Methods

3.1 Introduction

This study aims to explore the colour schemes used in contemporary casual VR games from the user's perspective, understand the impact of colour schemes on user response times, and to provide a basic facility to create adaptable colour schemes. The research uses a combination of qualitative and quantitative research methods. The debate between quantitative and qualitative methods is not antagonistic and there is complementarity between them (Pedone, 2000). The researcher first conducted a pilot study (In, 2017)to assess the feasibility of the research method, process, participants, and the need for research instruments. The card sorting method was used in a pilot study (Courage & Baxter, 2005; Grant & Berg, 1948) to explore the colour scheme of virtual games from the user's perspective. Next, an experimental study (Hulin & Katz, 1935; Tröndle et al., 2014) was used to explore the impact of colour schemes on user response times.

3.2 Research Sample

3.2.1 Pilot Study Participants

According to statistics, people aged 18 to 35 years are the main users of VR games. Three participants aged between 18- 35 were recruited for this study. The participants were two females and one male. All participants in the pilot study were from China, had experience in playing mobile games but not VR games, were right-handed, and were not colour-blind. Considering the influence of the environment on participants' performance, the researchers chose to experiment indoors.

3.2.2 Casual Game Menus

Casual games are easy to use and learn with simple mechanics and intuitive controls. In general, they have a low learning curve and can be appreciated quickly (Weizman, 2014). The participants in this study were gamers who had never been exposed to VR games before, and choosing casual games helped the participants to complete the task in an easy-to-manipulate state without consuming too much energy. Due to the wide variety of colours, the colour range for studying the entire game is too wide, so the colour range in this study is limited to the menu of virtual games.

3.3 Process Steps

Step 1: The researcher applied the purposive sampling method (Tongco, 2007). The 87VR Assistant application (87VR, n.d.) in mainland China is the main platform for downloading games on Oculus Quest 2 devices. This study used the 87VR Assistant ratings and the number of raters to filter the game. Ratings are compiled across five areas: Game Graphics, Game Sound, Game fun, Game Comfort, and Game Immersion, with a maximum score of 10 and a minimum is 0. A higher rating means the game has game graphics that are approved by players. Reviews and ratings above nine were screened as games for participants to experience.

Step 2: Find three participants for the pilot study through convenience sampling.

Step 3: Conduct the pilot study by inviting 3 participants to experience the game.

Step 4: All testing was conducted indoors. Participants signed a consent form, and the facilitator informed them of their right to abandon the test at any time.

Step 5: Before starting the game, the researchers asked the participants to take a colour-blindness test to eliminate colour-blind and weak people. Farnsworth Munsell 100 Hue Test was conducted on a Redmi laptop.

Step 6: Ten minutes before testing the game experiment, the facilitator introduced the participants to the study objectives and informed them of the estimated duration of the game experience. The Oculus Quest 2 pupil distance was adjusted for each participant, and the researchers adjusted the size of the headband to fit the user's head circumference. The researchers provided daily disposable contact lenses for nearsighted individuals to ensure participant comfort.

Step 7: A step-by-step presentation diagram of the click task was sent to the participant's smartphone WeChat 5 minutes before the start of the experiment. Considering the differences in button size and font colour, button selection and button fonts were specified with a maximum of four selection tasks per game design.

Step 8: The facilitator wears the Oculus Quest 2 device and installs the games, opens the Beat Saber game menu interface, debugs the game buttons, and then turns on the gaming device for players. Participants enter and observe the game menu for 1 minute to become familiar with it and how the joystick operates. At the same time, the host opens the Redmi computer to connect the Oculus Quest 2 with a 1.5-meter USB cable and projects the image of the VR device to the computer screen through the 87VR Assistant software, opening the Microsoft Xbox recording software and clicking record.

Step 9: Participants start to click on the task after the facilitator announces its start. During this time, no sound was emitted except that of the facilitator to prevent the participant from completing the experiment.

Step 10: After the participants have finished testing all the games, the facilitator uses an iPhone X to show the location of the colour cards in the screenshot of the game and explains to the participants that the location corresponds to the colour of the sorting card. Participants complete card sorting: 1. Participants begin card sorting by clicking on the link to the website (Uxtweak). 2. Participants access check the home page and the instructions page. 3. Participants drag and drop coloured cards onto the backgrounds or geometric shapes, buttons, and font sorting boxes. If they think that the colour cards are not in the game's colour scheme, they can choose not to drag and drop the colour cards. 4. Participants close the page and repeat other game card sorting.

Step 11: The researcher used the Popular placements matrix with the Uxtweak website to obtain the colour schemes of the four games.

Step 12: The researcher collected the data on user response times through the participants' test recording screen set up by Adobe Premiere software.

4. Results and Analysis

4.1 VR Casual Game Selection

87VR Assistant is a game downloader application for Oculus Quest 2 devices. There are 921 VR games, including 364 leisure games. The game selection is ranked according to the rating, and the statistical date is June 15, 2023. The game selection meets the following requirements. The selected games have the following conditions:

1. Casual games are available for download in the 87VR Assistant app.
2. Casual games have a score greater than nine and a rating count greater than 100.
3. Casual games have menus.
4. The researcher collected the number of ratings and scores of 364 casual games in 87VR Assistant and ranked them according to the high scores and low scores. Four games satisfy conditions 1 to 3, and the games boxed marked in red in the figure below are the selected games (Table 1).

Game Name	Rating	Number of Rating	Remarks
Beat Saber	9.3	434	
All-In-One Sports VR	9.1	404	
Angry Birds	9.1	196	
LES MILLS BODYCOMBAT	9.1	101	
Pierhead Arcade 2 VR	9	121	Without Menu
BoomBox	8.7	104	
Silhouette	8.6	115	
Party On	8.5	148	
Crow: The Legend quest	8.5	111	
Colombia in 360: Mompox - Timeless Magical Realism	8.4	101	
Three-quarters space station	8.3	123	
Dance Collider	8.3	113	
VR Ballcade	8.3	106	
Dayunlong VR	8.1	104	

Illustrated by author

Table 1: Ranking of Virtual Reality Leisure Games

4.2 Task Click Order

The task flow of each game design is shown below, where the numbers represent the order of participants' clicks, and the border around the numbers represents the location of the participants' clicks. Figures 1 through 4 show the click sequence of Beat Saber, All-In-One Sports VR, Angry Birds, and Les Mills Bodycombat, in that order.

Figure 1: Beat Saber Task Click Order

Figure 2: All In One Sports VR Task Click Order

Figure 3: All-In-One-Sports VR Task Click Order

Figure 4: Les Mills Bodycombat Task Click Order

4.3 Participants' Colour Blindness Test Results

The Farnsworth Munsell 100 Hue test results for all three participants were 0, with 0 being the highest score indicating no colour weakness or colour blindness, and the results for all three participants are shown (see Figure 5).

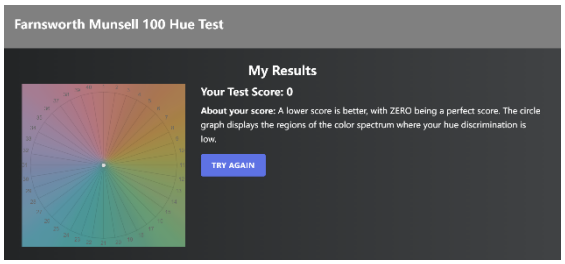
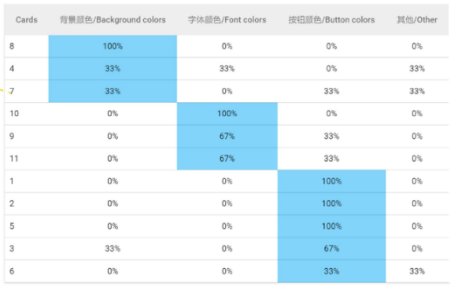


Figure 5: Farnsworth Munsell 100 Hue Test Results

4.4 Colour Scheme

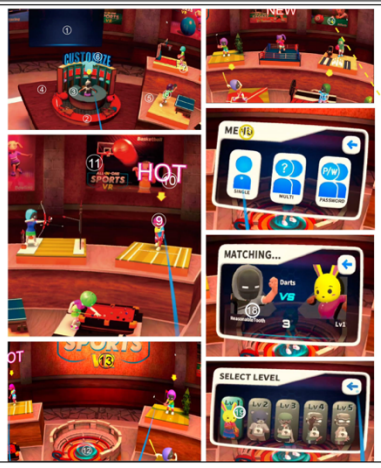
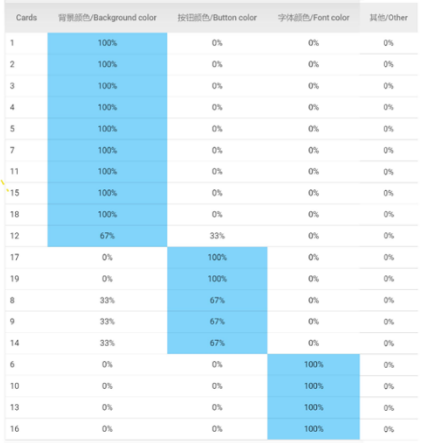
The third column in the top half of Table 2-5 shows the results of the popular placement matrix for the colours of the four-games, where the numbers on the second column correspond to the colour numbers in the third column. The percentages in the four right columns of the popular placement matrix indicate the percentage of participants who sorted cards of that colour into the corresponding sorting boxes. For example, in this pilot study, there were 3 participants and 67% background colour meaning that there were two participants who sorted the cards into the background colour sorting box. The percentage box cell is coloured blue, which means this sorting box is the most popular with participants. Participants putting the colour into the sorting box means that the participant considers this colour one of the colour schemes for this game.

The colour schemes were identified from the user's perspective using a card sorting method and a popular placement matrix. The colour schemes of four popular VR games are shown in the bottom half of Tables 2-5: Beat Saber (Table 2), All-In-One Sports VR (Table 3), Angry Birds (Table 4), and Les Mills Bodycombat (Table 5).

Game name	Color position in screenshot	Color cards result of popular placements matrix
Beat saber		

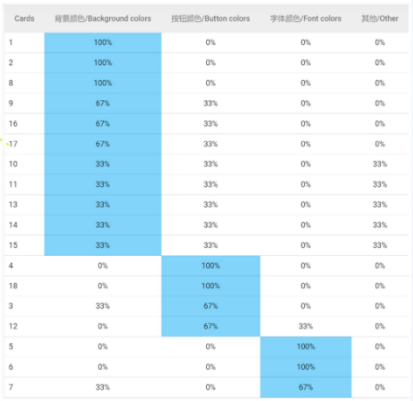
Color card number	1	2	3	4	5	6	7	8	9	10	11
Color scheme											
HSB	H: 211 S: 100 B: 88	H: 197 S:91 B:98	H: 244 S:34 B:26	H:232 S: 9 B: 84	H:197 S:100 B:75	H:228 S:100 B: 77	H:355 S:72 B:93	H:203 S: 87 B: 30	H:206 S: 12 B: 93	H: 206 S: 0 B: 100	H: 193 S: 98 B: 100

Table 2: Colour Scheme Result of Beat Saber

Game name	Color position in screenshot	Color cards result of popular placements matrix
All-In-One Sports VR		

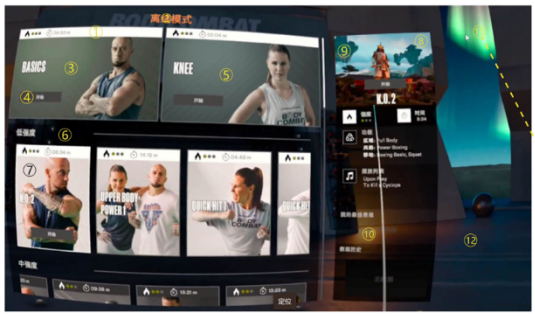
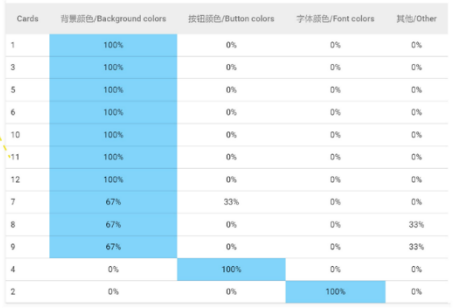
Color card number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Color scheme																			
HSB	H: 223 S: 67 B: 27	H: 1 S: 88 B: 90	H: 158 S: 20 B: 41	H: 357 S: 80 B: 44	H: 12 S: 60 B: 92	H: 194 S: 85 B: 88	H: 57 S: 48 B: 95	H: 94 S: 63 B: 73	H: 336 S: 86 B: 89	H: 40 S: 5 B: 98	H: 351 S: 85 B: 10	H: 172 S: 70 B: 68	H: 50 S: 80 B: 91	H: 190 S: 60 B: 84	H: 110 S: 48 B: 32	H: 33 S: 23 B: 22	H: 210 S: 77 B: 65	H: 19 S: 12 B: 54	H: 155 S: 57 B: 64

Table 3: Colour Scheme Result of All-In-One Sports VR

Game name	Color position in screenshot	Color cards result of popular placements matrix
Angry Birds		

Color card number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Color scheme																		
HSB	H: 12 S: 38 B: 66	H: 22 S: 63 B: 99	H: 193 S: 56 B: 61	H: 48 S: 79 B: 100	H: 67 S: 100 B: 97	H: 25 S: 11 B: 91	H: 45 S: 98 B: 100	H: 16 S: 64 B: 41	H: 304 S: 13 B: 54	H: 50 S: 7 B: 100	H: 128 S: 100 B: 64	H: 49 S: 44 B: 100	H: 19 S: 13 B: 34	H: 194 S: 98 B: 81	H: 4 S: 71 B: 85	H: 319 S: 52 B: 83	H: 230 S: 81 B: 27	H: 2 S: 81 B: 100

Table 4: Colour Scheme Result of Angry Birds

Game name	Color position in screenshot	Color cards result of popular placements matrix
Les Mills Bodycombat		

Color card number	1	2	3	4	5	6	7	8	9	10	11	12
Color scheme												
HSB	H: 2 S: 0 B: 100	H: 15 S: 58 B: 94	H: 100 S: 12 B: 49	H: 59 S: 22 B: 7	H: 163 S: 13 B: 46	H: 228 S: 66 B: 3	H: 16 S: 7 B: 90	H: 194 S: 35 B: 74	H: 186 S: 91 B: 34	H: 11 S: 45 B: 32	H: 142 S: 52 B: 80	H: 213 S: 60 B: 20

Table 5: Colour Scheme Result of Les Mills Bodycombat

4.5 User Response Time

Table 6 shows the results of user response time.

Game Name	Participants	Step1	Step2	Step3	Step4
		User reponse time (In Second)			
Beat saber	A	1.24	Missed	2.48 Misoperation time:3.20	2.28
	B	8.22 Recognition error time: 2.50	1.20 Misoperation time: 3.10	1.28 Misoperation time:1.02	1.06
	C	5.24	Missed	2.34 Misoperation time: 3.58	6
All-in-on sports	A	2.26 Misoperation time:3.36	Holding time:2.28 Animation time:1.34	2.02 Animation:0.44	1.48 (Less movement distance)
	B	4.28 Misoperation time: 2.30	Holding time: 5.20 Animation time: 1.34	2.54 Animation time: 0.44	1.18 (Less movement distance)
	C	No records	Holding time: 2.30	5.30 Seconds Animation time: 0.44	1.36 (Less movement distance)
	C Second time	6.30 Misoperation time: 1.18	Holding time: 1.24 Animation time: 1.34	2.48 Animation time: 0.44	0.34 (Less movement distance)
Angry birds	A	4.46 Animation time: 0.34	1.06 (Less movement distance) Animation time: 1.14	1 (Less movement distance) Animation time: 0.40	0.58 (Less movement distance
	B	3.42 Animation time: 0.34	2.34 (Less movement distance) Animation time: 1.14	3.34 (Less movement distance) Animation time: 0.40	1 (Less movement distance)
	C	Missed	6.14 (Less movement distance) Animation time: 1.14	1.38 (Less movement distance) Animation time: 0.40	1.24 (Less movement distance)
Les mills bodycombat	A	4.34	Missed	Missed	-
	B	No records	No records	No records	No records
	C	2.18	1	5.10	-

Table 6: User Response Time Results

5. Conclusion and Discussion

5.1 Conclusion

All VR user interfaces involve colour. Users must quickly and accurately recognise the information generated by colours to properly use the VR application. The present study investigated the colour schemes and response times of users of four VR games. Three local residents in Shanghai were recruited to conduct the pilot study of the games with different colour schemes and then participate in the card sorting. Based on the results of the pilot study, the colour schemes of the four VR games are summarised from the user perspective (Tables 2 to 5). The pilot study also investigated the impact of colour schemes on user response times. 2. During the All-In-One Sports VR gaming experience, participant C (Table 5) was unable to click the button for the third step, causing Participant C to repeat the experiment a second time. In the second experiment, user response times in the first and second stages of the experiment were significantly shorter for participant C (Table 5). There is a relationship between response time and user interface familiarity; The more familiar the user is with the interface, the shorter the response time, which is no longer affected by the colour scheme. In addition to the colour schemes, tests have shown that the size, shape, and position of the user interface buttons may also affect the user response time. The response time of the entire game's colour scheme must include the impacts of these factors.

5.2 Discussion

With the development of VR technology, VR applications have also been used in other industries. Although this study is based on the game's colour scheme, it can also be used as a reference for other colour designs in VR.

In the Les Mills Bodycombet game play experiment, according to the task, participants had to click on the background colour, but two out of three participants clicked on the background button colour. This phenomenon may be related to curiosity and habit.

It can also be associated with strong and easily recognizable colour contrast, due to its contrasting background colour and recognisable colour. There is also a difference in

interactive functionality between the buttons and backgrounds, as buttons are interactive while backgrounds are not. Colour attracts participants to the interactive buttons and creates a desire to click on them.

According to Linton et al., the components of a user interface are background, geometric shapes, buttons, and fonts. In this study, users categorised about 15% of the colour cards into other columns and had other user interface components from the user's perspective. Additionally, the researcher did not find any review literature on the classification of user interfaces from a graphical standpoint. Knowing the research in this area will help better understand the interface design in VR better to meet user needs and deliver a great user experience.

This study shows the impact of different colour schemes in a game on user response time. However, the researchers also noted that the size and position of buttons in the task as well as various user interface factors also affected user response times. The presence of these factors may influence our results. Therefore, in future studies, it is anticipated that these variables will be controlled to accurately assess the impact of colour scheme with fixed user interface to user response time. This study provides a new perspective and theoretical basis for understanding how a game's colour scheme affects user experience. The researchers expect to be able to obtain more accurate and in-depth results in future studies by further controlling the experimental conditions.

5.3 Research Implications

Theoretical Implication: In this study, researchers explored how colour affects human interaction with virtual worlds. From a semiotic perspective, one refers to Peirce's theory, which defines "semiotics" as the process by which humans perceive and interact with the world, creating meaning for their environment based on their perceptions and experiences (Peirce, 1991). However, despite the numerous applications of colourism in many fields, little research has been done to determine whether colourism as a theory affects the interaction of people with virtual worlds or not. This is a question that deserves further investigation. Colour is not just a part of visual perception; it is also an essential tool for understanding and explaining our world. Colour can influence psychological state and even modify behaviour. By studying into the role of colour in the interaction between humans and virtual worlds, designers can better understand the impact of colour on user experience and optimise design strategies, providing valuable reference information for designers.

Practical Implications: In this study, the researchers used the card sorting method to study colours, which has not been covered in previous studies. Card sorting is a standard user research method that helps researchers understand how users understand and organise information. In this study, researchers applied this method to the study of colour scheme research to understand how users perceive and understand colour by observing how they classify cards based on colour. This study provides a new research tool and method for other researchers. Other scholars can use our approach to explore the application of colour schemes and further advance the field of colour science and design.

Research Implications: Researchers initially analysed the relationship between colour schemes and user response times. The colour scheme can affect user response time to some extent. Additionally, we found that users' familiarity with the game also affects their response time. After collecting data on user response times, we found that the more familiar the game,

the shorter the user response time typically is. This may be because the more familiar users are with the game, the better they understand the game's colours and graphics in the game and are, therefore, able to respond more quickly. In addition, we also provide raw data for other researchers to refer to. This data includes the game's colour scheme and user response times. This data can not only help other researchers to deeply understand the relationship between colour schemes and user response times but also provide valuable reference materials for our future research. By deeply analysing the relationship between colour scheme and user response time, this study provides a new perspective and theoretical basis for game design and user experience research.

References

Ahn, J., Choi, S., Lee, M., & Kim, K. (2017). Investigating key user experience factors for virtual reality interactions. *대한인간공학회지, 36(4), 267–280.*

Christo, P. (2021, September 3). 45 Virtual Reality Statistics That Will Rock the Market in 2023. *Techjury*. Retrieved from https://techjury.net/blog/virtual-reality-statistics/

Coomans, M. K., & Timmermans, H. J. (1997, August). Towards a taxonomy of virtual reality user interfaces. In *Proceedings. 1997 IEEE Conference on Information Visualization (Cat. No. 97TB100165)* (pp. 279-284). IEEE. https://doi.org/10.1109/IV.1997.626531

Courage, C., & Baxter, K. (2005). Card Sorting. In *Understanding your users: A practical guide to user requirements methods, tools, and techniques* (pp. 217–244). Morgan Kaufmann Publishers.

Coursaris, C. K., & van Osch, W. (2016). A Cognitive-Affective Model of Perceived User Satisfaction (CAMPUS): The complementary effects and interdependence of usability and aesthetics in IS design. *Information & Management, 53(2), 252–264.* https://doi.org/10.1016/j.im.2015.10.003

87VR. (n.d.). *87VR official website*. Retrieved September 25, 2023, from https://www.87vr.com/

Grant, D. A., & Berg, E. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. *Journal of Experimental Psychology, 38(4), 404–411.* https://doi.org/10.1037/h0059831

Hoxmeier, J. A., & DiCesare, C. (2000). System Response Time and User Satisfaction: An Experimental Study of Browser-based Applications (Vol. 347). http://aisel.aisnet.org/amcis2000http://aisel.aisnet.org/amcis2000/347

Huang, K.-C., & Chiu, T.-L. (2007). Visual Search Performance on an LCD Monitor: Effects of Color Combination of Figure and Icon Background, Shape of Icon, and Line Width of Icon Border. *Perceptual and Motor Skills, 104(2), 562–574*. https://doi.org/10.2466/pms.104.2.562-574

Hulin, W. S., & Katz, D. (1935). The Frois-Wittmann pictures of facial expression. Journal of Experimental Psychology, 18(4), 482–498. https://doi.org/10.1037/h0056770

In, J. (2017). Introduction of a pilot study. Korean Journal of Anesthesiology, 70(6), 601. https://doi.org/10.4097/kjae.2017.70.6.601

Jacoby, R. H., & Ellis, S. R. (1992, June). Using virtual menus in a virtual environment. *In Visual Data Interpretation (Vol. 1668, pp. 39-48).* SPIE. https://doi.org/10.1117/12.59654

Jing, Z., Wang, D., & Zhang, Y. (2023). The Effect of Virtual Reality Game Teaching Technology on Students' Immersion. *International Journal of Emerging Technologies in Learning (IJET), 18(08), 183–195.* https://doi.org/10.3991/ijet.v18i08.37825

Khairunniza-Bejo, S., & Kamarudin, S. (2011). Chokanan Mango Sweetness Determination Using HSB Color Space. *2011 Third International Conference on Computational Intelligence, Modelling & Simulation, 216–221.* https://doi.org/10.1109/CIMSim.2011.45

Kim, Y. M., Rhiu, I., & Yun, M. H. (2020). A Systematic Review of a Virtual Reality System from the Perspective of User Experience. *International Journal of Human–Computer Interaction, 36(10), 893–910.* https://doi.org/10.1080/10447318.2019.1699746

Kimmons, R. (2020). Color theory in experience design. In *Learner and user experience research: An introduction for the field of learning design & technology.* EdTech Books. https://edtechbooks.org/ux/color_theory?action=print

Kramida, G. (2016). Resolving the Vergence-Accommodation Conflict in Head-Mounted Displays. *IEEE Transactions on Visualization and Computer Graphics, 22(7), 1912–1931.* https://doi.org/10.1109/TVCG.2015.2473855

Kwok, P. K., Yan, M., Chan, B. K. P., & Lau, H. Y. K. (2019). Crisis management training using discrete-event simulation and virtual reality techniques. *Computers & Industrial Engineering, 135, 711–722.* https://doi.org/10.1016/j.cie.2019.06.035

Linton, M. A., Vlissides, J. M., & Calder, P. R. (1989). Composing user interfaces with InterViews. *Computer, 22(2), 8–22.* https://doi.org/10.1109/2.19829

Liszio, S., & Masuch, M. (2016). Designing Shared Virtual Reality Gaming Experiences in Local Multi-platform Games (pp. 235–240). https://doi.org/10.1007/978-3-319-46100-7_23

Liu, W., Cao, Y., & Proctor, R. W. (2021). How do app icon color and border shape influence visual search efficiency and user experience? Evidence from an eye-tracking study. *International Journal of Industrial Ergonomics, 84, 103160.* https://doi.org/10.1016/j.ergon.2021.103160

Lyu, F., Xi, R., & Liu, Y. (2022). Color design in application interfaces for children. *Color Research & Application, 47(2), 507–517.* https://doi.org/10.1002/col.22726

Miller, R. B. (1968, December). Response time in man-computer conversational transactions. In *Proceedings of the December 9-11, 1968, fall joint computer conference, part I* (pp. 267-277).

Pallavicini, F., Pepe, A., & Minissi, M. E. (2019). Gaming in Virtual Reality: What Changes in Terms of Usability, Emotional Response and Sense of Presence Compared to Non-Immersive Video Games? *Simulation & Gaming, 50*(2), 136–159. https://doi.org/10.1177/1046878119831420

Pedone, C. (2000). El trabajo de campo y los métodos cualitativos. Necesidad de nuevas reflexiones desde las geografías latinoamericanas. *Scripta Nova. Revista electrónica de Geografía y ciencias sociales, 57*(1).

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education, 147,* 103778. https://doi.org/10.1016/j.compedu.2019.103778

Shu, Y., Huang, Y.-Z., Chang, S.-H., & Chen, M.-Y. (2019). Do virtual reality head-mounted displays make a difference? A comparison of presence and self-efficacy between head-mounted displays and desktop computer-facilitated virtual environments. *Virtual Reality, 23*, 437–446. https://doi.org/10.1007/s10055-018-0376-x

Siek H.L, Liew Y.M., Keoy K.H, & Cherukuri A. K. A study of the corporate design packaging of Malaysia's processed food, *Journal of Information & Knowledge Management, 22*(4), 1793-6926, https://doi.org/10.1142/S0219649223500260

Staggers, N., & Kobus, D. (2000). Comparing Response Time, Errors, and Satisfaction Between Text-based and Graphical User Interfaces During Nursing Order Tasks. *Journal of the American Medical Informatics Association, 7*(2), 164–176. https://doi.org/10.1136/jamia.2000.0070164

Tongco, Ma. D. C. (2007). Purposive Sampling as a Tool for Informant Selection. *Ethnobotany Research and Applications, 5*, 147. https://doi.org/10.17348/era.5.0.147-158

Tröndle, M., Kirchberg, V., & Tschacher, W. (2014). Is This Art? An Experimental Study on Visitors' Judgement of Contemporary Art. *Cultural Sociology, 8(*3), 310–332. https://doi.org/10.1177/1749975513507243

Wall, E. S. (2021). *An empirical study of virtual reality menu interaction and design.* Mississippi State University.https://www.proquest.com/intermediateredirectforezproxy

Weizman, A. (2013). Designing Casual Serious Games in Science. In *European Conference on Games Based Learning* (p. 561). Academic Conferences International Limited. https://doi.org/10.4108/sg.1.3.e6

Yue, G. (2021). 3D User Interface in Virtual Reality (pp. 418–423). https://doi.org/10.1007/978-3-030-90176-9_54

Zyda, M. (2005). From visual simulation to virtual reality to games. *Computer, 38*(9), 25–32. https://doi.org/10.1109/MC.2005.297

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