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COLOR PSYCHOLOGY IN VIDEO GAMES: A Systematic Literature Review

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ABSTRACT

The video game industry is expanding, and it is necessary to determine if color psychology applies to its graphical interface. The main objective is to understand how the use of color psychology in video games has been studied. This study conducts a systematic review of color theory and its impact on the graphical interface. Existing studies highlight the role of color in communicating with users and enhancing game mechanics and narratives. This proposal recommends standardized criteria for evaluating color psychology in video games.

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1. Introduction

Color is perceived by humans under a triple nature, we have the physical nature, the emotional nature and the physiological nature. Each of them has its own field of research and has had seminal works that have vertebrated said fields. Since Newton first spoke about color theory in 1665, a substantial amount of re-search has focused on this area, including studies on the nuances of user perception since Goethe (Elliot, 2015; Elliot & Maier, 2012; Heller, 2004; Goethe, 1810; Terwogt & Hoeksma, 1995). These studies will be elaborated on in the following sections. Color psychology was created to study the emotional aspects of color. In the field of color psychology, notable research conducted by Heller (2004) has emphasized the emotions evoked in users. These emotions influence individuals to behave in different ways when exposed to specific chromatic stimuli. And lastly, from a physiological standpoint, functional magnetic resonance imaging analysis has been employed to examine how different hemispheres of the brain react to chromatic visual stimuli, uncovering distinct patterns of response (Bird et al., 2014; Siok et al., 2009)

While research on how color affects users in graphical interfaces has been conducted, there is a limited number of studies specifically focused on the field of video games (Geslin et al., 2016; Haghi et al., 2019; Joosten et al., 2010; Terron-Lopez, 2022). However, the video game market is expanding and holds considerable importance in our society. In 2022, the global video game market generated revenues of $184.4 (DEV, 2023). According to the consultancy Newzoo (*Newzoo Global Games Market Report 2022*, 2023), this market is projected to reach $211 billion in 2025. The primary driver for this growth is the mobile gaming sector, which alone generated $103.5 billion in revenue in 2022. Consequently, this work aims to propose future research directions in this area, identifying potential areas of interest based on the theoretical framework that has been studied.

The objective of this article is to address the question: How has the use of color psychology in video games been studied? There is extensive research, as will be discussed later, that explores how to apply color psychology in various fields. However, it has been observed that in the area of video game graphical interfaces, no specific model currently exists. This article aims to provide a starting point that can serve as a foundation for future research in this regard. To achieve this, specific objectives have been defined: to explore academic research in this field and examine the emotions color generates in users.

2. Materials and Methods

To achieve these objectives, this article employs a systematic review methodology based on methodological guidelines established by authors such as Grijalva (2019), Gómez-Luna (2014), and Ortiz (2005). Furthermore, The PRISMA systematic review checklist was used to ensure the methodical construction of the study (Page et al., 2021).

The criteria established for the review arise from the need to address the dual nature of the study. The aim is to link emotions with video games through color psychology. Therefore, on one hand, psychology must be connected to video games, and on the other, psychology must be linked to emotions, as this is the connection that can be made with the user. The criteria used to select and group articles are as follows (where Criterion 2 was limited by the requirement that one or both established sub-criteria must be met to be considered valid):

Criterion 1: Address the psychology of color as applied to video games.

Criterion 2: Explore the relationship between color psychology and emotions.

Sub-criterion 2.1: Potential for analysis in the graphical interface.

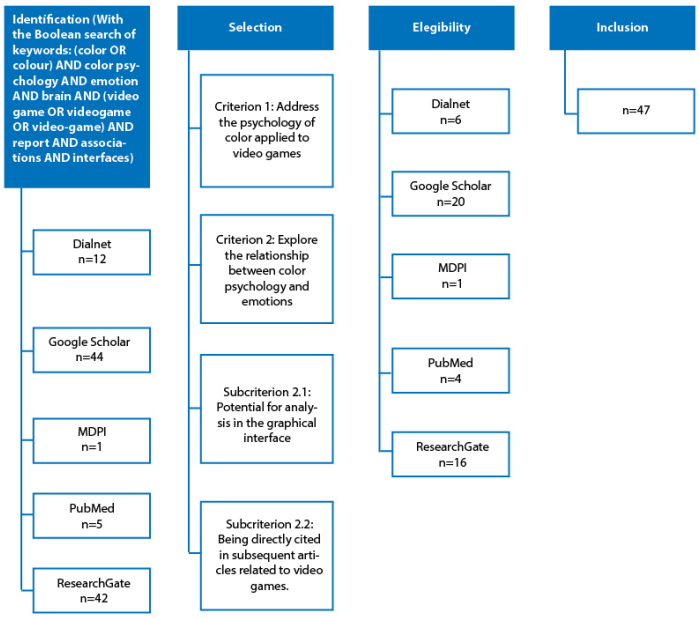
Sub-criterion 2.2: Being directly quoted in subsequent video game related articles.

Articles that did not meet the previously established criteria were excluded. Additionally, the bibliographies of the selected articles were reviewed to identify the most relevant studies upon which they were based, ensuring that they also met the established criteria, and subsequently included in the article pool. Additionally, a search of websites was performed to identify potential unpublished studies that had been reviewed online.

The main databases (presented in alphabetical order) used for the research were: Dialnet, Google Scholar, PubMed, and ResearchGate. The keywords employed included: Color (as well as its British spelling, colour), color psychology, emotion, brain, video game (also including its alternative forms, videogame and video-game), report, associations, and interfaces. Figure 1 represents the PRISMA systematic review flowchart, including the original number of articles identified under the cited search

criteria (n=104), broken down by database, with a further breakdown of the articles eligible and included.

Figure 1. PRISMA flowchart for article selection and inclusion



Source: Own elaboration, 2024.

Based on the databases and the keywords used, a cross-reference table of articles containing both items was prepared (Table 1).

From each article, the main conclusions, sample sizes, and experimental methods of their studies were gathered. However, since these experiments yielded non-quantitative results and are independent of each other, it was not considered appropriate to establish a direct comparison between them. Rather, the focus is on explaining their individual relevance and conclusions.

Table 1. Database

Keyword	Database	Author	Title	Year
Color psychology, emotions	Google Scholar	Heller E.	Psicología del color: cómo actúan los colores sobre los sentimientos y la razón	2004
Color, emotions	Google Scholar	Terwogt MM, Hoeksma JB.	Colors and emotions: Preferences and combinations	1995
Color psychology	BubMed	Elliot AJ, Maier MA	Color psychology: effects of perceiving color on psychological functioning in humans. Annu Rev Psychol	2014
Color psychology	Dialnet	Elliot AJ, Maier MA.	Color and Psychological Functioning	2016
Color psychology	Google Scholar	Johann Wolfgang Von Goethe.	Goethe's Theory of Colours	1810
Color, brain	Dialnet	Siok WT, Kay P, Wang WSY, Chan AHD, Chen L, Luke KK, et al.	Language regions of brain are operative in color perception. Proc Natl Acad Sci USA	2009
Color, brain	PubMed	Bird CM, Berens SC, Horner AJ, Franklin A.	Categorical encoding of color in the brain. Proc Natl Acad Sci USA	2014

Videogames, report	Google Scholar	Asociación Española de Empresas Productoras y Desarrolladoras de Videojuegos y Software de Entretenimiento (DEV)	Libro Blanco del Desarrollo Español de Videojuegos. 2022	2022
Videogames, report	Google Scholar	Newzoo Global	Games Market Report 2022	2023
Color, emotions, videogames	Google Scholar	Terrón-López, P	El uso del color en la interfaz gráfica de los videojuegos	2022
Emotions, videogames	Researchgate	Joosten E, Van Lankveld G, Spronck P.	Colors and Emotions in Video Games	2010
Color, emotions, videogames	Researchgate	Geslin E, Jégou L, Beaudoin D, Oliveira MM.	How color properties can be used to elicit emotions in video games	2016
Color, emotions, videogames	Google Scholar	Haghi M, Alizadehashrafi B, Nasr-Esfahani S.	The Effect of the Colours on the Perception of Time among Players of Computer Games: A Narrative Review.	2019
Color, emotions, videogames	Google Scholar	Emiliano Labrador	El uso del color en los videojuegos	2020
Color psychology, emotions	Google Scholar	Wassily Kandinsky.	De lo espiritual en el arte	1911
Color psychology	Google Scholar	Johannes Itten	The Art of Color the Subjective Experience and Objective Rationale of Color	1961
Color, emotions	Google Scholar	Mehrabian A, Valdez P.	Effects of Color on Emotions	1994
Color, emotions	Dialnet	Ou LC, Luo MR, Woodcock A, Wright A.	A study of colour emotion and colour preference. Part I: Colour emotions for single colours	2004
Color, emotions	Dialnet	Ou LC, Luo MR, Woodcock A, Wright A.	A study of colour emotion and colour preference. Part III: Colour preference modeling	2004
Color, emotions	Dialnet	Ou LC, Luo MR, Woodcock A, Wright A.	A Study of Colour Emotion and Colour Preference. Part II: Colour Emotions for Two-Colour Combinations.	2004
Color, Associations	Google Scholar	Levitan, C.A.; Ren, J.; Woods, A.T.; Boesveldt, S.; Chan, J.S.; McKenzie, K.J.; Dodson, M.; Levin, J.A.; Leong, C.X.R.; Van Den Bosch, J.J.F.	Cross-Cultural Color-Odor Associations	2014
Color psychology	Dialnet	Elliot, A.J.	Color and Psychological Functioning: A Review of Theoretical and Empirical Work	2015
Color, Associations	PubMed	Tham, D.S.Y.; Sowden, P.T.; Grandison, A.; Franklin, A.; Lee, A.K.W.; Ng, M.; Park, J.; Pang, W.; Zhao, J.	A Systematic Investigation of Conceptual Color Associations.	2020
Color	PubMed	Morita, A.; Kambara, T	Bizarreness and Typicality Effects of Color on Object Recognition Memory.	2021

Color, emotions, videogames	Researchgate	Wolfson S, Case G	The effects of sound and colour on responses to a computer game	2000
Color, emotions, videogames	Researchgate	Ravaja, N., Salminen, M., Holopainen, J., Saari, T., and Laarni,	Emotional response patterns and sense of presence during video games: Potential criterion variables for game design	2004
Color, interface	Researchgate	Richard Cook; Paul Kay; Terry Regier	The World Color Survey	2009
Color psychology	Google Scholar	Rider, R.	Color Psychology and Graphic Design Applications	2009
Color, emotions, videogames	Researchgate	De Melo, Celso M., Gratch, Jonathan	The effect of color on expression of joy and sadness in virtual humans	2009
Color psychology	Researchgate	O'Connor, Z.	Colour Psychology and Colour Therapy: Caveat Emptor	2011
Color, emotions	Google Scholar	Rivas Yuste, M.I.	Psicología Del Color : Cómo Influye El Color a Nuestra Percepción y Emociones	2017
Color, videogames	Google Scholar	Scott Rogers	Level Up! The Guide to Great Video Game Design	2014
Color, videogames	Researchgate	Joshua P. Salmon, Sarah M. Dolan, Richard S. Drake, Graham C. Wilson, Raymond M. Klein, and Gail A. Eskes	A survey of video game preferences in adults: Building better games for older adults	2017
Color, videogames, emotions	Researchgate	Evi Joosten, Giel van Lankveld, Pieter Spronck	Influencing Player Emotions Using Colors	2012
Color, interface	Google Scholar	Nicolás-Sáenz, L.; Ledezma, A.; Pascau, J.; Muñoz-Barrutia, A.	ABANICCO: A New Color Space for Multi-Label Pixel Classification and Color Analysis.	2023
Videogames, report	Google Scholar	Maroto, R.; Alegría, P.; González Lorca Presidente de AEVI José María Moreno, A.	La Industria Del Videojuego En España En 2021; 2022	2022
Videogames, color, reaction time	Researchgate	S Wolfson, G Case	The effects of sound and colour on responses to a computer gam	2000
Color, reaction time	Semantic Scholar	Birgitta Dresp-Langley and John M. Wandeto	Human Symmetry Uncertainty Detected by a Self-Organizing Neural Network Map	2021
Videogames, color, reaction time	Researchgate	Song, AFaugeras O, Veltz R	A neural field model for color perception unifying assimilation and contrast	2019
Color, reaction time	Google Scholar	Balakrishnan GUppinakudru GGirwar Singh G et al.	A Comparative Study on Visual Choice Reaction Time for Different Colors in Females	2014
Color, reaction time	Google Scholar	Iglesias-Martínez MHernaiz-Guijarro MCastro-Palacio J et al.	Machinery Failure Approach and Spectral Analysis to Study the Reaction Time Dynamics over Consecutive Visual	2020

			Stimuli: An Entropy-Based Model	
Color, reaction time	Google Scholar	Heidari-Gorji H, Zabbah S, Ebrahimpour R	A temporal neural network model for object recognition using a biologically plausible decision making layer	2018
Color, reaction time	Google Scholar	Moscoso del Prado Martin F	The thermodynamics of human reaction times	2009
Color, emotions	Researchgate	Cai DGoto SShinohara T et al.	Synesthetic color scheme in Fantasia	2010
Color, reaction time	Researchgate	Amini Vishteh R, Mirzajani A, Jafarzadehpour E	Evaluation of Simple Visual Reaction Time of Different Colored Light Stimuli in Visually Students	2019
Color, reaction time	Researchgate	Balakrishnan G, Uppinakudru G, Girwar Singh G et al.	A Comparative Study on Visual Choice Reaction Time for Different Colors in Females	2014
Color, reaction time, video games	ResearchGate	Jin YKim JYoo J	Study on reaction time depending on display parameters of gaming displays	2023

Source: Databases and the keywords used, a cross-reference table. 2024

3. Results

After conducting the bibliographic review, it has been determined to organize the information into two sections, each arranged chronologically:

- Color psychology
- Color and reaction time
- Color in video games

It was deemed necessary to include a general introduction to color psychology to gain a better understanding of its application in the context of video games. To gain a clearer understanding of the relationship between each article in the "Color Psychology" section, we have chosen to include an example that demonstrates how this study is reflected in video games. This serves to emphasize the close connection that exists between color psychology and video games.

3.1. Color psychology

The psychology and theory of color is a subject that has been studied in various fields. In this first part, the aim is to conduct a bibliographic review that highlights the most significant milestones in this area.

The Theory of Color is not solely studied within the realm of Newton's physics, but also in terms of user perception. Goethe (1810) argues that both the mechanisms of sight and the brain are involved in perception. He asserts that what we see is not solely determined by matter but also depends on the user's perception and subjectivity. His contributions regarding the chromatic circle, the definition of primary and secondary colors, and the exploration of chromatic harmonies extend into the realm of emotional transmission, influencing the observer's experience. Thanks to Goethe's color wheel, the process of combining colors becomes much simpler. In the context of video game interfaces, complementary colors are employed. For instance, Super Mario (1985) where the protagonist Mario wears red, and his brother Luigi wears green. The intention is to emphasize one element over another or to convey a sense of complementarity.

In 1911, Kandinsky (1911) discussed the psychological effect of color, once again emphasizing the active role of the user in the artistic work rather than being a mere spectator. In his book, he explores the range of emotions that colors can independently convey, causing a mood vibration in the user. He affirms that individuals have direct associations with colors, which can evoke different emotions depending on the hue. For instance, Kandinsky suggests that yellow can elicit an acidic sensation due to

its association with lemons. The emotions he discusses, such as in the case of yellow, are evident in the yellow hue of Pikachu from the Pokémon video game (1998). In addition to conveying a lively and vibrant quality, the yellow color also signifies electrification.

Johannes Itten (1961) discussed the Theory of Color in Design in his book *The Art of Color: The Subjective Experience and Objective Rationale of Color*, where he analyzed both the physical and emotional aspects of color. This analysis encompasses the visual, emotional, and symbolic dimensions. Itten explored the color wheel, seven degrees of contrast, and various color harmonies, examining a total of 28 masterpieces by painters such as Picasso and Klee. The color analysis conducted across visual, emotional, and symbolic domains is readily apparent in the HUD (Head-Up Display) of numerous video games. For instance, a health potion is typically depicted in red, as this color is commonly linked to blood, and by extension, vitality.

The article *The Effects of Color on Emotions* (Mehrabian & Valdez, 1994) examines the emotional impact that variations in the saturation and brightness of seven colors can have on users. The study sample consisted of 250 students from the University of California. The research findings revealed that highly saturated colors elicit a greater sense of excitement, while darker colors can provoke aggression, anger, and hostility. Furthermore, the study demonstrated that the sensations evoked by colors showed little variation between men and women. The colors were classified as blue, green, purple/violet, orange, yellow, and red. These assertions regarding saturated colors are observable in video games such as Tetris (1984), whereas those statements about darker hues, as exemplified by Dark Souls (2011), evoke feelings of aggression, anger, and hostility in players.

Just a year later, a study on color and emotions was conducted involving children aged 7 and 11, as well as adults (Terwogt & Hoeksma, 1995) The study concluded that: a) Color and emotion preferences change with age, b) The combinations of colors and emotions are closely related between children aged 7 and 11, and c) Colors and emotions maintain consistent associations across all age groups.

Eva Heller (2004) conducted a widely referenced study in scientific literature [with over 1,500 citations on Google Scholar at the time of writing this text). The study included a sample size of 2,000 individuals from different professional backgrounds and various locations in Germany. It seeks to demonstrate that colors are not combined solely for aesthetic reasons but that the associations between feelings and colors are deeply rooted in universal experiences and language. Heller asserts that these associations are not accidental but based on, deeply rooted, authentic universal experiences. Thirteen psychological colors are analyzed in the study, starting from primary and secondary colors, and progressing to hybrids as they are combined and mixed. The study confirms that people have a wider range of emotions than that of their perceived color, and as so, each color can be assigned to more than one emotion. The emotions that Heller asserts colors evoke are evident in a multitude of video games. For instance, the color green, which the author links to hope, is prominently displayed in Zelda's attire (1986-2023), symbolizing the hope of rescuing her people. Similarly, the regal connotations of violet are reflected in Fortnite's violet chests, denoting an epic quality surpassing others. The tranquil aura conveyed by blue is also manifest in video game settings where this color signifies a slower-paced level compared to the rest.

In the same year, a series of three articles (Ou et al., 2004) discussed the relationship between color and emotion, focusing on single-color emotions, the combination of two colors, and color preference modeling.

The first article presents a psychophysical experiment conducted with 31 observers, including 14 British and 17 Chinese participants. The observers evaluated 20 colors on 10 scales measuring color and emotion. The research results indicate that the emotional response to each color varied depending on the nationality of the participants, particularly in relation to scales measuring time-relaxation and like-dislike.

In the second paper, the analysis focused on eleven color-emotion scales. It was observed that there was a gender difference between males and females, while no significant cultural differences were found between British and Chinese observers.

In the third paper, the results obtained indicate that predicting color combination preferences based solely on color emotions is complicated. The study also sheds light on the relationship between color preference and color harmony, demonstrating that color preference is associated with color harmony. The connection established by chromatic harmony among individuals closely aligns with the principles expounded by Goethe and Kandinsky. In the video game Journey (2012), every scene is imbued with

analogous chromatic harmony, a deliberate choice intended to foster tranquility and encourage exploration within the game's world. This harmony is achieved using orange analogues for outdoor environments and blue analogues for indoor spaces.

In the article *Language Regions of Brain Are Operative in Color Perception* (Siok et al., 2009), the analysis is conducted using magnetic resonance imaging to examine how the different hemispheres of the brain respond to various visual stimuli, specifically focusing on stimuli presented in the right visual field (RVF). The study reveals that the brain regions responsible for color perception exhibit significantly greater activation when exposed to stimuli in the RVF compared to the left visual field (LVF). Furthermore, the study demonstrates a close relationship between language-related brain regions and the visual field, as these regions are activated when the participants are exposed to colored elements. Notably, when the colors presented in the RVF belong to different lexical categories, the activation of the V2/3 visual region is significantly higher compared to other color conditions. This study highlights the frequent necessity of incorporating explanatory texts within video games, allowing players to choose whether to engage with them. The research underscores a profound interplay between brain regions associated with language and the visual domain. This interaction showcases the potential for language to bolster the emotional impact of colors experienced during gameplay, emphasizing the intricate connection between linguistic and visual stimuli.

In the analysis of color psychology in the film *Fantasia*, synesthesia is studied as a neurological condition in which stimulation of one sensory pathway elicits automatic responses in another. Specifically, sound-color synesthetes perceive colors and shapes in response to sounds and music. The study evaluated 43 synesthetes, focusing on those with the highest scores in tests of pitch, chord, and musical key. The results indicated that these individuals consistently associated specific colors with musical keys, particularly major keys. Using the k-means clustering method, representative colors were identified for each pitch, chord, and key. These colors were compared with those used in Walt Disney's film *Fantasia*, revealing interesting parallels, although there is no evidence that the artists of the film were synesthetes. This research highlights how synesthesia can influence the structured perception of sound and its visual representation (Cai et al., 2010).

In *Categorical Encoding of Color in the Brain* (Bird et al., 2014) a study is conducted to examine how the brain responds to chromatic samples with two shades of the same color compared to samples with two different colors. Functional magnetic resonance imaging (fMRI) analysis is used to observe the brain's reactions to these stimuli. The investigation reveals that categorical and metric pitch differences are encoded in qualitatively different ways and in distinct brain regions. These findings have implications for the ongoing debate about the origin and nature of color categories, and they contribute to a better understanding of how the brain processes color. Additionally, the study identifies brain regions that independently encode differences in color category and the magnitude of hue difference.

Other investigations aim to determine the close relationship between color and culture. In the study *Colour-Smell Intercultural Associations*, researchers examine the intercultural associations between color and smell to determine if these associations are based on structural, statistical, or semantic reasons (Levitan et al., 2014). The study involves 122 participants from six different cultural groups who generate associations with the same set of 14 odors. The study concludes that culture plays a significant role in cross-modal color-odor associations, which are likely to develop through experience. The findings of this study offer valuable insights for refining color choices, particularly when seeking to establish specific emotional tones within scenes or environments, extending their impact beyond mere visual cues. This significance is especially noteworthy in contexts such as video games, where graphical realism may not be highly emphasized. In such instances, color has demonstrated its capacity to amplify the desired emotions, effectively enriching the intended conveyance of feelings.

In *Color Psychology: Effects of Perceiving Color on Psychological Functioning in Humans* (Elliot & Maier, 2014), the authors assert that there are connections between color and people's psychological functioning. They also confirm that color can influence people's behavior when exposed to a product, thereby favoring its consumption. This supports Eva Heller's claim that color goes beyond mere aesthetics and can evoke emotions in individuals.

In the same year, a study (Hussain et al., 2014) was conducted based on a video game called Pan's Remarkable Adventure (2014), designed to enhance visual function in individuals with abnormal visual development. The video game aimed to improve contrast sensitivity through training. During the research, the non-amblyopic eye was covered to enhance the response of the amblyopic eye. The

rationale was that perceptual learning involves practicing visual tasks to enhance visual function in amblyopic individuals.

The study involved 10 amblyopic children and 10 adults who played the game at home, using their amblyopic eye, for an average of 37 sessions. The results of the research indicate that contrast thresholds significantly improved in adults but not in children. However, both groups showed improvement in logMAR acuity.

A year later, Elliot conducts a theoretical and empirical review of the psychology of color (Elliot 2015). In his research, he emphasizes that color, such as tone, hue, and luminosity, should not be evaluated in isolation. Factors like distance, viewing angle, amount and type of ambient light, as well as the presence of other colors in the background and environment, must also be considered. He recommends conducting studies with large sample sizes and controlled color stimuli.

In the same year, Moutoussis (2015) studied how color influences the visual perception of shapes. He observed that the relationship between color and shape in the early stages of visual processing is supported by the presence of dual-selective neurons and functional magnetic resonance imaging (fMRI) data, which indicate the existence of information regarding color and shape combinations in early visual areas. In his research, he also argues that color perception may depend on the luminance surrounding the shape, as observed in achromatic objects on chromatic backgrounds, similar to what occurs in the video game Inside (2016).

In 2016, Elliot and Maier revisit the topic of color and its psychological function (Elliot & Maier, 2016). In their article, they emphasize the importance of carefully calibrating luminosity and color hue when studying color from a psychological perspective. They also conclude that red is associated with love, passion, and sexual arousal. They attribute these associations to the red hearts of Valentine's Day and the use of red lights to signal sexual availability in brothels. A central premise of their study is that color effects are context specific. For example, green may be linked to money in the United States, but in a kitchen setting, it can be associated with spoiled food due to its connection to mold. This theory finds manifestation in video games, contingent upon their themes. The red hue of the mushroom in Super Mario conveys energy and vitality, whereas in Red Dead Redemption II (2018), it signifies injury or damage. In the realm of video games, it is imperative that elements possessing visual correspondence to the tangible world retain their coloration. Likewise, universally recognizable symbols like the red heart representing "life," or the green energy bar, persist consistently across various video games.

Within the article *A systematic investigation of conceptual color associations* (Tham et al., 2020), a systematic and cross-cultural mapping of conceptual color associations is carried out using the complete set of shades from the World Color Survey (WCS). For this, two experiments are carried out. The first shows the associations that exist for the basic terms of color in English (black, white, red, yellow, green, blue, brown, purple, pink, orange, and grey). And in the second experiment, they try to determine which WCS-specific physical colors are associated with which linguistic concepts. The results reveal the following associations in all cultures: white: purity; blue: water/sky; green: health; purple: royalty; pink: "feminine" features; red and orange: enthusiasm in Chinese; red: attraction in English. Likewise, Ekman (1971) revealed that the 6 basic emotions are experienced the same way in all cultures.

A year later, *Bizarreness and Typicality effects of color on objects Recognition Memory* (Morita & Kambara, 2021) studies how the change in the color of objects affects memory when they are modified by colors that are not their own. In the experiments carried out on 49 students, it is shown that the color does not affect the identification of the objects, but on the contrary, it is affirmed that they are recognized more quickly if their typical color is maintained. An unusual color applied to an object can even inhibit memory performance instead of improving it. The data obtained from the study, in words of the authors, are interesting for the advertising field since it is observed how visual stimuli and attention influence memory.

3.2. Color and reaction time

Reaction time is the interval between sensory stimulation and the behavioral response (Moscoso del Prado Martin, 2009). It depends on visual image parameters (Iglesias-Martínez et al., 2020) and involves rapid integration of visual characteristics to form a coherent representation (Heidari-Gorji et al., 2018). The visual field, processed in parallel channels, influences reaction time through chromatic and achromatic factors (Balakrishnan et al., 2014; Song et al., 2019). Reaction time is linked to chromaticity changes at constant luminance.

The visual system processes light from photoreceptors to the primary visual cortex, with brightness affecting reaction time (Dresp-Langley & Wandeto, 2021). A study on Iranian students showed significant differences in reaction times to colored light stimuli, with red being the fastest (Amini Vishteh et al., 2019). Warm colors were perceived as more pleasant, aiding comprehension (Balakrishnan et al., 2014).

In video games, reaction time is influenced by contrast ratio and response time (Jin et al., 2023; Wolfson & Case, 2000). Higher contrast ratios and faster response times improve reaction time, enhancing gaming performance. Overall, the results underscore that, while refresh rate and color have a minor impact on input latency, they do not significantly affect reaction time.

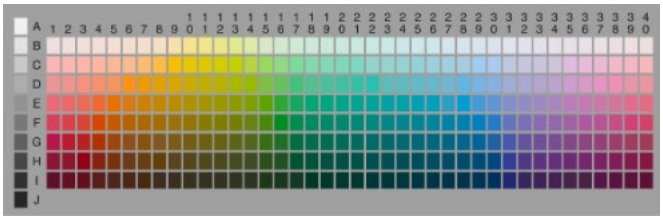
3.3. Color in video games

Wolfson and Case (2000) conducted a study researching the relationship between sound and color during a video game. In specific video games, they modified the background color (red/blue) and the sound (high/low). It was observed that players who used a blue screen gradually improved throughout the session, while those who used a red screen started to worsen around the middle of the game session. Surprisingly, the sound had little impact, and the combination of red/noise led to more excitement and better gameplay. This study contributes to our understanding of the use of red and blue colors in certain video games to increase their difficulty.

In the 2004 study titled *Emotional response patterns and sense of presence during video games: Potential criteria variables for game design*, (Ravaja et al., 2004) researchers examined the emotional responses of 37 students to a specific series of video games: Tetris, Super Monkey Ball 2, Monkey Bowling 2, and James Bond 007: NightFire. The emotional responses were evaluated based on joy, pleasant relaxation, anger, fear, feelings of depression, and sense of presence. Each of the analyzed video games evoked different emotions in the players, and in games like James Bond 007: NightFire, these emotions could be influenced by the player's personality. This study helps in designing different emotionally optimal versions of a game tailored to users with varying personality traits.

To gain a better understanding of how users perceive colors, it is necessary to study the lexicon universally used to name them. The World Color Survey (WCS), created by Richard Cook et al. (2009), developed a universal lexicon for color terms. The survey was administered to 2,616 participants from 110 languages, and their responses to a standardized set of 330 "Munsell" color samples were observed (Figure 2).

Figure 2. WCS-Munsell-chart



Source: Cook et al., 2009.

The study identified eight groups of statistical significance, described by basic English color terms: "RED" (red), "GREEN" (green), "BLUE" (blue), "GRUE" ("green or blue"), "YELLOW-OR-ORANGE" (yellow or orange), "BROWN" (brown), "PINK" (pink), and "PURPLE" (purple). Additionally, three achromatic color categories were included: "BLACK" (representing the darkest achromatic color in the WCS table), "GRAY" (including achromatic samples excluding black and white), and "WHITE" (representing the lightest achromatic color). This study enabled the universal naming of colors, resulting in a total of 11 universally interpreted color terms in the WCS.

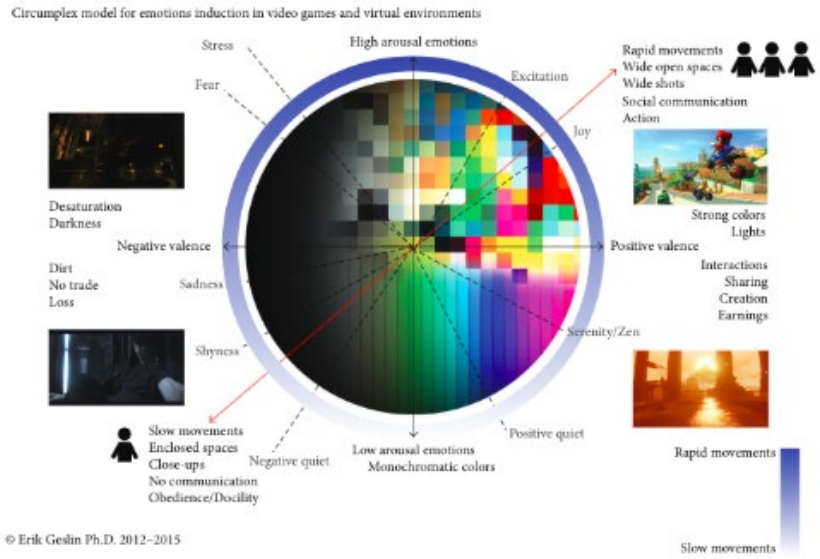
In the field of graphic design, the psychology of color plays a significant role, as demonstrated in the thesis *Color Psychology and Graphic Design Applications* (Rider, 2009). The study involved a sample of 264 university-age participants, including 113 men and 180 women. It built upon the colors and shades examined in the research by Mehrabian and Valdez (Mehrabian & Valdez, 1994) emotions of the colors blue and yellow in different shades. The results re-vealed that 48% of individuals aged 21-34 named navy/midnight as their favorite shade of blue, compared to 32% of individuals aged 35-54 and 21% of individuals aged 55 or older.

Color psychology is also studied in its impact on the field of video games. The colors used in video games have an effect on players' emotions (Joosten et al., 2010) In this research, the participants used a video game that featured four different colors, each associated with a specific emotion. The obtained emotional responses were as follows: the color red evoked a negative emotional response associated with excitement, while the color yellow elicited a positive emotional response. It is worth noting that inexperienced players displayed more explicit reactions to colors compared to experienced players.

The research developed by De Melo and Gratch (2009) helps to utilize color to influence the perception of emotions in virtual humans, which is particularly valuable in virtual environments like video games. In the analyzed virtual models, distinct features characterize the mappings of joy and sadness. Four characteristics have been defined: brightness, saturation, temperature, and the number of colors. The results showed that images portraying happiness tend to be brighter, more saturated, and have a richer color palette compared to images depicting sadness. Furthermore, the study highlights that color plays a more significant role than the realism of these virtual humans when it comes to conveying emotions. In a 2011 article (O'Connor, 2011), O'Connor questions some of the statements that have been made, particularly those based on a limited color spectrum or isolated study conditions that deviate from the natural conditions to which users are exposed.

The emotional impact of colors on players was, studied again in 2016, in an experiment involving 85 participants, including 31 women and 54 men (Geslin et al., 2016; Terron-Lopez, 2022). Participants were exposed to 24 randomly presented game frames, and their emotions were assessed based on parameters such as sadness/joy, calm/excitement, and fear/confidence. To accomplish this, the researchers developed a tool called "color scripting" to measure the extent of chromatic diversity, color saturation, brightness, and even movement speeds. Through this tool, they examined how these factors influenced users' emotions, as shown in Figure 3.

Figure 3. Tentative circumplex model for color scripting in video game



Source: Geslin et al., 2016

In the book *Level Up! The Guide to Great Video Game Design* (Rogers 2014), the significance of using color in the design of levels, settings, maps, characters, and icons is high-lighted. According to Rogers, color serves to identify elements and evoke emotions throughout different phases of the game. As Labrador (2020) and Terrón-López (2022) later affirmed, it reinforces the narrative of the game and enhances the personality of the characters and settings. Consequently, the importance of color in the graphic interface of video games is clearly demonstrated.

Color has been extensively studied in the audiovisual field, particularly in cinema and serialized audiovisual content, to understand its impact on users and the emotions it conveys (Rivas Yuste, 2017, p.25). In the study it is stated that *Color is another form of language, aiding us in self-expression. We learn to use and interpret it from childhood*, highlighting color as an expressive element in conveying feelings and emotions.

The article titled *A Survey of Video Game Preferences in Adults: Building Better Games for Older Adults* (Salmon et al., 2017) analyzes video games targeted towards the adult population to determine their preferences compared to younger audiences. The findings indicate that this adult audience prefers video games that are easy to learn and play, while also providing a challenge for the player. Furthermore, it is observed that enhancing color and brightness contrast on screens can improve playability within this age range. However, it's worth noting that this article does not discuss the emotions generated using colors and their variations in lightness at any point.

A year later, in Joosten's (2012) study on emotions and video games, it is noted that gamers experience emotions while playing video games, and these emotions are one of the main reasons for playing. A video game was evaluated in which four different colors were used, and each color was associated with a specific emotion. The color red was found to evoke a negative emotional response, while yellow evoked a positive emotional response. The researchers concluded that the data obtained can be valuable for game designers, as the strategic use of color can significantly improve the gaming experience. These findings are consistent with those discovered by Heller (2004) and Johannes Itten (Mehrabian & Valdez, 1994), highlighting the strong connection between studies on color and the emotions that players experience while playing video games.

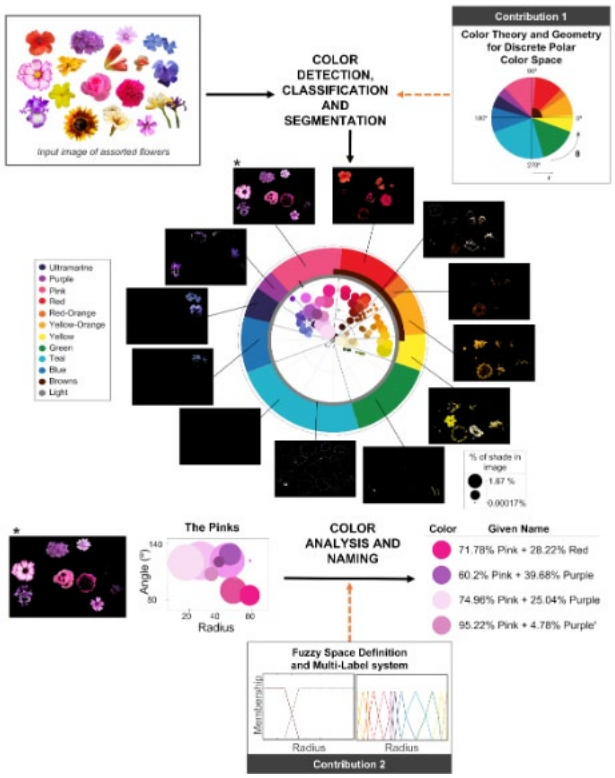
In 2019, a study focused on how color affects the narrative of video games was conducted (Haghi et al., 2019) This study reviewed various research articles from the year 2000 on-wards, exploring the effects of colors on the perception of time in video games. The authors noted a lack of previous research on the psychology of color specifically in relation to the perception of time in video games. They emphasized the need for further investigation into the graphic interface and aesthetics of video games to enhance user popularity and attract wider audiences. The study also concluded that the color red leads users to perceive that they have spent more time playing the game compared to users exposed to screens dominated by blue.

In *The Use of Color in Video Games* by Emiliano Labrador (2020), an analysis of color theory in video games is conducted, exploring how color influences player interaction. The study concludes that color plays a crucial role in reinforcing the game's narrative by emphasizing elements such as flashbacks, flash forwards, character moods, and in-game damage. The thoughtful selection of colors in video games also enhances accessibility for players with visual impairments. The study provides a set of guidelines to ensure equal gameplay experience for individuals with color-related visual limitations. These guidelines include avoiding dark backgrounds, favoring bluish green over yellowish green, and refraining from color combinations such as red/green, yellow/luminous green, pink/light blue, and blue/violet.

In a 2022 study, the color and graphic interface of video games are analyzed, focusing on eight evaluation criteria: Color and Technology, Color and Characters, Color and Settings, Color and HUD, Color and Mechanics, Color and Narrative, Color and Player Taxonomy, and Color and Disability (Terron-Lopez, 2022). These criteria are applied and studied in four video games with different graphic styles: Super Mario Bros 3, Columns, Journey, and Red Dead Redemption II. The study's conclusions are primarily based on Heller's Color Psychology (2004), which explores the emotional responses evoked by color. These findings may assist designers in making informed decisions to effectively apply color psychology in the graphical interface of video games, guided by the defined criteria.

In 2023, a study titled *ABANICCO: AB ANgular Illustrative Classification of Color* (Nicolás-Sáenz et al., 2023) was conducted, presenting an automated pixel color classification system. This system aimed to advance the existing lexicon for color by updating the data from the World Color Survey (Cook et al., 2009) The study proposed a method that combined geometric analysis, color theory, fuzzy color theory, and multi-label systems for automatic pixel classification, as illustrated in Figure 4. The objective was to minimize bias arising from human perception and contextual factors, and this approach was compared with the ISCC-NBS standardized color system. The study resulted in the identification of 12 chromatic categories for analyzing color in screen pixels, one more than those obtained in the WCS. These categories include Pink, Red, Red-Orange, Yellow-Orange, Yellow, Green, Teal, Blue, Ultramarine, Purple, Brown, and Achromatic.

Figure 4. ABANICCO: AB ANgular Illustrative Classification of Color

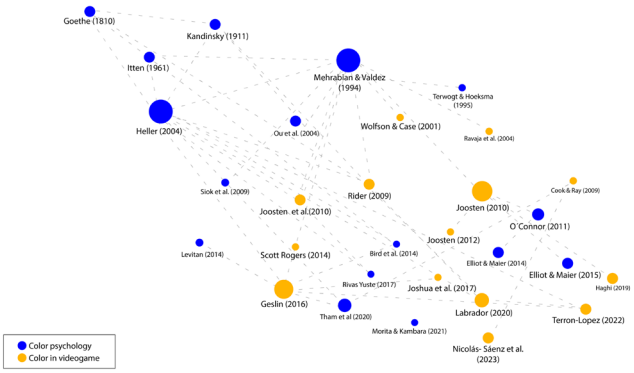


Source: Nicolás-Sáenz et al., 2023

The ABBANICO color classification has been found to be particularly relevant to the study of color in video games because it classifies color specifically in the pixels that appear on the screen. Considering that color pixels constitute one of the primary means through which a video game communicates interactions to the user, this classification system is considered to provide a potentially relevant starting point for the study of color in this medium.

In order to visualize the connections among the various sources reviewed, a nodal map has been created and is presented in Figure 5. The nodo.org tool was utilized to transfer the systematic review conducted. The map reveals larger nodes that prominently feature the contributions of Heller and Mehrabian & Valdez. These nodes are connected to other references in color psychology as well as color in video games. It is notable that the number of nodes associated with color psychology is considerably fewer compared to those associated with color in video games.

Figure 5. Interactive Node map of the reviewed papers, a further breakdown



Source: Terron-Lopez, 2023

4. Discussion

As research on color psychology has progressed, there has been an increasing emphasis on understanding the emotions elicited by color in users. This not only demonstrates its psychological impact but also suggests that it can be measured at the neural level. Some studies have even identified brain regions that independently encode differences in color category and hue variation (Bird et al., 2014; Siok et al., 2009).

Neural Basis of Video Gaming: A Systematic Review examines the relationship between video games and their neural correlates across six distinct sections: attention, visuospatial skills, cognitive workload, cognitive control, skill acquisition, and reward processing. However, the study concludes that the neuroimaging data are not conclusively linked to the underlying cognitive processes. (Palaus et al., 2017)

As has been observed, color psychology has a significant influence on video games, ranging from Goethe's theory (1810) to the studies of Morita, A.; Kambara (Elliot & Maier, 2016). The results obtained from these studies have been applied in various ways within the graphical interfaces of video games. These influences are primarily evident in the following aspects:

- Characters: Color psychology serves to reinforce personalities and emotions within video games, facilitating player identification and engagement throughout the gaming experience. Additionally, it aids in distinguishing antagonists, as exemplified by the case of Super Mario, where complementary colors are employed.
- Scenarios: Color psychology contextualizes the in-game actions, enhancing narrative elements. The variation in scenarios serves to propel game progression, as demonstrated in titles like Super Mario and Journey.
- HUD: Utilizing color psychology, the HUD enables swift identification of on-screen elements, provided they are distinct from the background. This can be observed in games like Fortnite.
- Mechanics: Color psychology supports the implementation of game mechanics by drawing attention to paths, objects, and power-ups. These visual cues facilitate player communication without the necessity of HUD indicators, similar to the damage feedback system in Red Dead Redemption.
- Narrative: Colors contribute to storytelling and character development within video games, as evident in the case of Journey, where color aids in conveying the narrative or adding nuances to characters' stories.

These aspects, along with the RT, influence the player's experience. In addition, the RT is implied in the previous aspects, and it will be managed by the game designers depending on the game goals. Part of the works analyzed show that there are factors influencing human reaction time (RT) in response to visual stimuli and in video gaming. The findings support theories that visual characteristics of an event are quickly integrated by the cognitive system to form a coherent response, with reaction times dependent on visual image parameters. In testing reaction times to different colored light stimuli, red light elicited the fastest reactions. This aligns with previous research indicating that warm colors like red, orange, and yellow are more comprehensible. These insights are relevant for designing visual displays and user interfaces to optimize human response times. For example, in Fortnite a quick RT will be needed, while in Journey will be a slow RT.

Studies in video gaming by Wolfson and Case (2000) and Jim, Kim, and Yoo (2023) highlight the significance of screen technology specifications—specifically high contrast ratios and fast response times—in reducing reaction times and enhancing gaming performance. The correlation between these factors suggests that prioritizing such screen specifications may benefit gamers. Reaction time has a complex nature, influenced by both chromatic and achromatic factors, and the integration of visual information at various stages of the visual processing pathway. Understanding these determinants of reaction time has practical applications in ergonomic design, educational tools, competitive gaming, and neurocognitive research, with future studies needed to further explore these interactions.

Research has tried to establish links between color (individually or in combination with other sensory inputs such as sound) and emotion (De Melo & Gratch, 2009; Joosten et al., 2012; Joosten et al., 2010; Ravaja et al., 2004; Wolfson & Case, 2000) specifically in the field of videogames. However, these studies do not refer to an established coding of colors or sounds, which hinders comparison or

replication. This emphasizes the need to establish a common coding of sensory inputs when conducting research on the importance of color in video games. Video games defy classification by color due to their diverse utilization, as observed. The choice of color is contingent upon aesthetic or artistic intentions, narrative requisites, or even gameplay mechanics. Notably, research by Labrador (2020) and Terrón-López (2022) indicates that vibrant colors or those with heightened contrast find prevalence in video games demanding rapid gameplay, exemplified in titles like Super Mario, Fortnite, and Candy Crush. Conversely, games emphasizing narrative depth and requiring a calmer approach employ softer, less contrasting hues.

The lexicon used to define colors holds significant importance as it enables the naming of colors using universal terms, as demonstrated in the World Color Survey (WCS) conducted by Richard Cook et al. in 2009, which defined eleven colors. To update the approach of naming colors and isolate them from the user's perception, a study has been conducted that specifically defines the chromatic range within the pixels of the screen, known as ABANICCO (Nicolás-Sáenz et al., 2023)

Color plays a significant role in identifying elements and evoking emotions during different game phases, reinforcing the narrative and enhancing the personalities of characters and settings (Rogers, 2014). However, color perception is not uniform throughout an individual's lifespan (Salmon et al., 2017). Therefore, coding should consider age cohorts when studying the effects of specific colors or combinations on study subjects. Color holds substantial significance across all genres of video games, as evident from observations, serving as a pivotal element in gameplay and intensifying emotional conveyance. Furthermore, owing to technological progress, individuals with specific chromatic visual impairments can engage in gameplay unhindered. Increasingly, video games are incorporating features that allow color readjustment tailored to these disabilities, exemplified by Red Dead Redemption 2, as investigated by Terrón-López (2022)

The discoveries made regarding color and emotions are independent of culture, and each color is associated with a specific emotion. The basic emotions are also universally experienced. For example, white represents purity, blue represents water/sky, green represents health, purple represents royalty, pink is associated with "feminine" features, red and orange signify enthusiasm in Chinese culture, and red represents attraction in English culture. Within the chromatic range, saturated colors evoke excitement, while darker and less luminous colors can elicit aggression, anger, and hostility. It is recommended to apply this knowledge in graphic interface designs to enhance communication with users and reinforce narratives, particularly in video games.

While there is extensive research on color theory and psychology, very few studies have focused specifically on the psychology of color in the graphical interface of video games, as highlighted in this literature review. Considering that the video game industry is currently outperforming the film industry in terms of revenue (Maroto et al., 2022), it is advisable to conduct research specifically on the psychology of color in video games, exploring how the colors used in graphical interfaces impact users during gameplay and the emotions they evoke.

As expounded within this article, no colors inherently confer specific advantages over others. However, what remains certain is the existence of pre-established associations that fortify the emotions evoked by colors. Vibrant or subdued hues can influence the pace of gameplay, either accelerating or decelerating it. Moreover, colors aid in identifying distinct in-game elements, enhancing the execution of mechanics, or re-shaping character personalities.

Further research is proposed using the ABANICCO method (Nicolás-Sáenz et al., 2023) to analyze the colors used in a significant list of video games from the user's perspective. It would be advisable to carry out this analysis based on established criteria, such as those of Terrón-López (2022), which result in specific emotional associations for each color range in relation to the graphical interface. The original ABANICCO colors are Pink, Red, Red-Orange, Yellow-Orange, Yellow, Green, Teal, Blue, Ultramarine, Purple, Brown, and Achromatic. It is proposed to subdivide the achromatic category into three, leaving the term "Achromatic" to identify black and expanding the original range to include Gray and White.

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