Fostering Inclusivity and Creativity: A Card Game for Color Perception and Inclusion

Paula Escudeiro and Márcia Campos Gouveia
Games, Interaction and Learning Technologies, Polytechnic University of Porto, Porto, Portugal

pmo@isep.ipp.pt
magia@isep.ipp.pt

Abstract: The gaming industry has undergone a dramatic transformation in recent years, with inclusivity emerging as a core value in the development of new games. Despite these efforts, there remains a gap in the inclusivity of visually impaired individuals in gaming. This paper seeks to address this gap by asking: How can game design enhance colour perception and inclusivity for visually impaired players? The industry has recognized the importance of addressing the needs of individuals with diverse needs and abilities and has responded with innovative approaches aimed at creating games that are accessible to all. One such approach is the development of a card game that has been meticulously designed to stimulate color perception and promote the inclusion of visually impaired individuals. Chroma Harmony is a pioneering mobile application meticulously crafted to facilitate users' understanding of color concepts and the outcomes of different color combinations. Its primary aim is to promote inclusivity by offering features tailored to individuals with visual impairments. Leveraging the innovative ColorADD system, it revolutionizes the perception and communication of color, thereby paving the way for enhanced participation in gaming among those with vision impairments. Its main objective is to paint a cube by combining cards in the player's possession to achieve the closest or exact combination to the objective. With each move, a new card is presented, challenging players to choose the best one to achieve their goals and improve their color perception abilities. By the end of the game, players will have a better understanding of how colors are combined, preparing them for real-world scenarios. Furthermore, the game features a multiplayer mode to foster a sense of community and healthy competition among players. This multiplayer mode not only promotes inclusivity but also provides an opportunity for players to collaborate and challenge each other fostering community sense. In terms of competencies and skills, this game aims to develop several key abilities in its users such as the ability to identify colors, the ability to combine different colors effectively and the necessary motivation and drive for results. By focusing on these competencies and skills, Chroma Harmony strives to provide a comprehensive and engaging experience for all players, regardless of their abilities or background. This study highlights the ongoing challenge in the gaming industry to enhance accessibility and inclusivity, especially for visually impaired individuals, while also standing as a testament to the industry's commitment to inclusivity and innovation, pushing the boundaries of what is possible in gaming.

Keywords: Inclusive Gaming; Color Perception; Visual Impairment; Game Design; Accessibility.

1. Introduction

The gaming industry has experienced a significant transformation in recent years, with inclusivity becoming a central focus in the development of new games. This shift reflects an acknowledgment of the diverse needs and abilities of players, leading to the creation of innovative games that prioritize accessibility for all. However, there is a notable gap in game development that fully integrates visually impaired players. This paper aims to explore this gap by addressing the research question: How can game design techniques be innovatively applied to enhance color perception and inclusivity for visually impaired individuals? One approach is the development of Chroma Harmony, a groundbreaking card game that stimulates color perception and promotes the inclusion of visually impaired individuals.

Chroma Harmony uses the innovative ColorADD system to facilitate players' understanding of color concepts and outcomes of different color combinations. The game also includes a multiplayer mode that fosters community and healthy competition, encouraging collaboration and friendly challenges among players. Furthermore, the game helps players develop key abilities such as color identification, effective color combination, and motivation for achieving goals. By emphasizing these competencies, Chroma Harmony delivers a comprehensive and engaging experience for all players, regardless of their abilities or background. This is an approach that not only contributes to the discourse on inclusive gaming but also provides a practical example of how game design can be utilized to bridge the accessibility gap for visually impaired individuals.

Chroma Harmony can extend its impact by collaborating with educational institutions to teach color theory and inclusivity, as well as with museums, art galleries, and cultural centers. Its availability on various devices will allow it to reach a wider audience and foster a community of players who share their art and experiences online. Ultimately, Chroma Harmony's focus on inclusivity, accessibility, and education positions it as a leading example of the industry's dedication to creating immersive and welcoming gaming experiences for all.

Moreover, the paper is structured as follows: the Introduction section provides an overview of the project, discussing the motivation and background for developing Chroma Harmony, as well as its innovative features and impact on the gaming industry. The Related Work section reviews existing literature and projects related to inclusivity in gaming, color perception, and similar game concepts. The Methodology section outlines the core idea and design philosophy behind Chroma Harmony, including the project's objectives. The Game Design & Development section discusses the game design and the use and implementation of Dynamic Difficulty Adjustment (DDA) in Chroma Harmony. The Evaluation & Quality Control section covers the evaluation process and quality control measures, including testing methodologies and results. Finally, the Conclusions section summarizes the findings and discusses the implications of the project, as well as future research and development.

2. Inclusive Education through Gamification

The concepts of inclusive education and serious games have been extensively studied in recent years. These themes intersect to provide a pathway toward addressing broader societal challenges and promoting access to education and technology for individuals with diverse needs and abilities.

G. K. Verma (2016) emphasizes the importance of UNESCO's initiatives and global conferences that support educational and social inclusion for children with special needs. Although progress has been made in promoting inclusive education, gaps still exist in the implementation of these policies across different countries and regions. Vulnerable and marginalized groups often face significant challenges related to social exclusion and limited access to educational opportunities.

Jayalath and Esichaikul (2020), as well as Molina-Carmona and Llorens-Largo (2020), explore the impact of gamification and advanced technology in motivating and engaging learners, particularly in blended e-learning environments and vocational training. By incorporating game dynamics, mechanics, and components, these approaches aim to enhance learning experiences and improve educational outcomes.

Furthermore, engaging in playful activities can enhance the learning process through multisensory stimulation and immersive experiences. That's why authors like Paula Escudeiro et al. are developing assistive technologies and inclusive pedagogical models to provide the blind and deaf communities with access to digital educational content. This highlights the importance of inclusive educational environments and technological solutions to promote accessibility and integration (Escudeiro et al., 2017, 2022; Marques et al., 2019).

These authors also discuss the potential of serious games to help individuals develop new skills and improve existing ones (Escudeiro et al., 2017, 2022; Marques et al., 2019). These games are particularly beneficial for populations that face barriers to traditional educational resources, such as the visually impaired or those with other disabilities. Inclusive games utilize cognitive models and multimedia learning principles to support learning for diverse audiences.

In fact, the utilization of serious games for educational purposes, as explored by Carvalho and Coelho (2022), has become an increasingly common practice. Serious games leverage the inherent motivation and engagement of games to support education, health, marketing, and social awareness.

Overall, these studies and projects provide valuable insights into how inclusive education, digital empowerment, and serious games can intersect to address societal challenges and create more equitable access to education and technology. This research supports the development of innovative approaches to game-based learning and digital inclusivity, such as the Chroma Harmony project, which leverages these concepts to promote understanding and inclusion for visually impaired individuals in gaming.

However, in comparing our study with these prior works, the Chroma Harmony project contributes a unique focus on the intersection of inclusive game design and colour perception training for visually impaired users. Unlike previous studies that broadly address inclusivity or focus on general gamification strategies, Chroma Harmony specifically aims to improve colour differentiation skills using the ColorADD system, a novel approach that has not been extensively explored in the context of serious games.

By addressing these points, future iterations of Chroma Harmony and related studies can build on this foundation to further refine the approach and enhance its educational and inclusive potential.

3. Methodology

Chroma Harmony is a serious game centered on education, color perception, and inclusion. It strives to introduce an innovative concept for games-based learning, utilizing advanced technologies and a fresh approach to teaching color theory and inclusivity, particularly for visually impaired individuals. By offering a comprehensive, engaging experience, Chroma Harmony serves as a model for blending entertainment with meaningful learning, fostering an understanding of color concepts and promoting a sense of community among players of all abilities.

3.1 Concept

This project involves the design and development of an innovative card game, Chroma Harmony, which aims to stimulate color perception and promote the inclusion of visually impaired individuals through the use of the ColorADD system. The game provides an interactive platform for players to assume the role of artists as they recreate and color impressive three-dimensional objects. The process begins with the conceptualization of the game, based on objectives of color perception and inclusion, and drawing inspiration from principles of universal design and inclusive gaming. Throughout the game, the ColorADD system is integrated to assist players with visual impairments in distinguishing and understanding color combinations.

The gameplay centers around players using color cards to combine colors and complete artworks. The game includes basic singular colors and special cards drawn from a randomly generated deck to keep the experience fresh and engaging. As players advance, the game introduces increasingly complex objects and combinations to challenge their color perception and matching skills. This progression is essential for sustained engagement and skill development. A reward system based on the scores achieved in each stage allows players to earn collectible cards showcasing their results, which vary in rarity depending on their performance. The multiplayer mode fosters community building, collaboration, and healthy competition among players.

In terms of user testing and iteration, the project includes collecting feedback from diverse groups, including players with and without visual impairments, to assess the game's inclusivity, playability, and appeal. This feedback is used to refine the game mechanics, ColorADD integration, and overall gameplay to enhance the player's experience and achieve project objectives.

3.2 Objectives

The project focuses on fostering inclusivity and creativity in gaming by introducing Chroma Harmony, a card game that encourages players to explore color combinations while promoting the inclusion of visually impaired individuals. By integrating the ColorADD system, the game becomes accessible and engaging for all players. As players progress, they develop perceptual and strategic decision-making skills, engaging with a diverse cast of characters and rich narratives that foster empathy and artistic expression. Chroma Harmony sets a new standard in the industry by delivering an immersive, inclusive gaming experience that both entertains and educates players on color perception and inclusion. As such, the project aims to:

- Promote understanding of colors and their combinations by enabling players to explore and experiment with a wide range of color combinations and facilitating a deeper understanding of how different colors interact and how these interactions can be applied in creative and real-world contexts.
- Encourage inclusion of visually impaired players by leveraging the ColorADD system to create a game that is accessible and enjoyable for visually impaired players and removing barriers to participation by offering features such as screen readers, customizable color palettes, and tactile feedback.
- Develop perceptual and strategic decision-making skills by encouraging players to analyze, plan, and execute color combinations to achieve artistic goals and fostering critical thinking through the progression of difficulty and variety in the game's challenges.
- Engage players with compelling, authentic characters, by introducing a diverse cast of characters, including visually impaired and sighted artists, to foster empathy and understanding and building character-driven narratives to enhance player engagement and promote inclusion.
- Stimulate creativity and artistic expression by providing a platform for players to express themselves artistically through color and design and encouraging experimentation and personal interpretation in the creation of three-dimensional artworks.

Overall, the project is centered on creating an engaging and inclusive gaming experience that not only entertains but also educates players on the nuanced aspects of color perception and inclusion. By thoughtfully designing

game mechanics and integrating innovative systems like ColorADD, Chroma Harmony sets a new standard for accessible and inclusive gaming in the industry.

4. Game Design and Development

The project centers on the development of a comprehensive card game designed to foster color perception and inclusion for visually impaired individuals through the innovative use of the ColorADD system. The game begins with a homepage displaying the game name and logo, followed by a login page for players to access their data or create an account. Once logged in, players encounter a menu with options such as single-player and multiplayer modes, a tutorial on how to play, an about the game section, and game settings for personalizing aspects like visuals, audio, and accessibility.

The game features both single-player and multiplayer modes. In single-player mode, players are given an unpainted canvas and a set of cards. They must combine color cards to paint sections of the canvas within a time limit, earning scores based on accuracy and completion time. In multiplayer mode, two players take turns painting a shared canvas and must strategically choose whether to paint a clean area, contest an opponent's work, or recolor their own work.

The game incorporates various types of cards, including basic cards (one color), palette cards (choose one color from a selection), prism cards (which combine with any other card to generate the correct color), diluent cards (which clear the canvas), mirror cards (duplicate the last played card), and RNG cards (which generate a card with a randomly chosen color).

Victory in multiplayer mode is determined by the highest score, which is calculated based on the accuracy of color choices in each painted section of the canvas. The game rewards players with collectible cards and character lore, creating an immersive and rewarding experience that emphasizes both creativity and competition.

Table 1: Game actions.

ID	Game mode	Trigger	Object	Action	Result
1	Single player	Puzzle	Player's hand	Level begins	The player receives 5 cards for their hand. The stopwatch is started
2	Single player/Multiplayer	Player	Player's hand	The player selects 1 'basic' card and 1 section	The section is painted with color. The card leaves the player's hand. The score is updated. The player receives 1card for their hand
3	Single player/Multiplayer	Player	Player's hand	The player selects 2-3 'basic' cards and one section	The section is painted by combining the colors of the cards. The cards leave the player's hand. The score is updated. The player receive s 2-3 cards for their hand
4	Single player/Multiplayer	Player	Player's hand	The player chooses a 'palette' car	X colors are presented to the player for them to choose. The card takes the value of the chosen color and goes to the player's hand
5	Single player/Multiplayer	Player	Player's hand	The player combines a 'prism' card with any other card and selects a section	The section is painted with the correct color. The cards leave the player's hand. The score is updated. The player receives 1 card for their hand
6	Single player/Multiplayer	Player	Player's hand	The player selects a 'thinner' card and a section	The object's section loses its assigned color. The card leaves the player's hand. The score is updated. The player receives 1 card for their hand
7	Single player/Multiplayer	Player	Player's hand	The player selects a 'mirror' card	All cards played by the player so far are presented. The player selects an option. The card goes to the player's hand

ID	Game mode	Trigger	Object	Action	Result
8	Single player/Multiplayer	Player	Player's hand	The player selects an 'rng' card and a section	The section is painted with a randomly chosen color. The card leaves the player's hand. The score is updated. The player receives 1 card for their hand
9	Single player	Stopwatch	Stopwatch	The stopwatch reaches the limit	The level ends, and the final score is calculated and assigned
10	Single player	Puzzle	Puzzle	The puzzle is completed	The final score is assigned. Level rewards are assigned and added to the p layer's collection
11	Multiplayer	Puzzle	Player's hand	The game begins	Players receive 5 cards for their hand. The stopwatches for each player are set to 2m30s. The starting player is decided by chance. The starting player's stopwatch starts counting
12	Multiplayer	Chronometer	Chronometer	The player's stopwatch reaches the limit	The player whose stopwatch reaches the limit loses the match. The level ends, and the final score is calculated and assigned

4.1 Dynamic Difficulty Adjustment (DDA)

To better match the difficulty of gameplay with the skills and experience of players, a passive form of Dynamic Difficulty Adjustment (DDA) is intended to be implemented into the game. DDA is a game design approach that dynamically adjusts the level of challenge based on a player's performance, ensuring a balanced and enjoyable experience for all skill levels (Oostendorp, van der Spek, & Linssen, 2014).

In Chroma Harmony, the DDA system will revolve around the use of the Lucky Card, a special card that can transform into any color the player needs. The influence of the Lucky Card on the gameplay will change according to the player's score and the time spent playing.

The DDA is activated as follows: if a player accumulates more than a certain threshold of points, the Lucky Card will revert to a normal card, reducing its influence on the game. Conversely, if the player's score falls below the designated threshold, the Lucky Card retains its original transformative power, helping the player progress. This system ensures that players of varying skill levels can maintain an engaging and balanced experience as they play.

5. Evaluation and Quality Control

Testing is a critical component of modern software development, essential for ensuring the quality and functionality of an application across a range of anticipated scenarios. This project emphasizes user interaction, focusing on usability, playability, stability, and performance.

To assess the project's technical requirements and measure the degree of fulfillment, the development team employs the Quantitative Evaluation Framework (QEF). QEF serves as a foundational tool for evaluating the project's technical aspects, allowing the team to measure the level of fulfillment for each requirement and ensure the game adheres to established quality standards (Escudeiro & Bidarra, 2008; Escudeiro & Escudeiro, 2012, 2013; Escudeiro et al., 2013; Marques et al., 2018).

Through technical testing under QEF, the team conducts an in-depth analysis of the game's capabilities, limitations, and potential performance issues. This methodical approach enables a thorough evaluation of key aspects of the application, such as functionality, adaptability, and usability. By systematically assessing the degree of fulfillment for each technical requirement, the team gains valuable insights into the project's current state and can make informed decisions about necessary adjustments and areas for improvement.

The structured nature of QEF promotes accountability and continuous improvement, providing a clear roadmap for achieving the game's objectives. Additionally, this framework fosters efficient communication among team members, encouraging collaboration and a shared understanding of the project's progress and goals.

To ensure the evaluation was comprehensive and representative, participants for the testing sessions were recruited based on specific criteria. The recruitment targeted a diverse group of users, including both visually impaired individuals. Participants were informed about the nature of the study and provided written consent to participate, ensuring ethical standards were upheld.

The test sessions were conducted in a controlled environment, where participants were asked to perform a series of tasks within the game that assessed their ability to differentiate and combine colours according to the ColorADD system. Observers recorded the participants' performance and feedback, focusing on their interaction with the game interface, ease of use, and overall experience.

The QEF evaluates the project across several dimensions: functionality, adaptability, and usability. Functionality encompasses aspects such as gameplay, collection, and features, measuring how effectively the game fulfills its intended purpose and objectives. Adaptability evaluates the game's flexibility and accessibility, including its capacity for maintenance, versatility, and accommodation of different user needs. Usability focuses on the user interface and experience, assessing elements like menu navigation, content quality, and integrity (Escudeiro & Bidarra, 2008; Escudeiro & Escudeiro, 2012, 2013; Escudeiro et al., 2013).

In the final evaluation, Chroma Harmony achieved the following scores: 93.868% in functionality, reflecting its success in gameplay, collection, and features; 58.333% in adaptability, indicating potential areas for improvement in versatility and accessibility; and 100% in usability, demonstrating excellence in menu navigation, content quality, and integrity.

By using QEF and regularly reviewing the project's progress, the development team can ensure that Chroma Harmony meets high standards of quality and delivers an engaging, accessible, and inclusive gaming experience.

6. Conclusions

In conclusion, the development of Chroma Harmony, an inclusive game designed to promote engagement for people with vision impairments, has been a significant accomplishment. By incorporating the innovative ColorADD system, the game successfully meets the unique needs of individuals with visual impairments, enabling them to enjoy a rewarding and immersive gaming experience.

Significant effort was invested in meeting the outlined objectives, and most of these goals were achieved. Chroma Harmony stands as a testament to dedication to inclusivity and accessibility, offering a platform where all players can explore and appreciate color concepts and combinations. This experience not only enhances players' understanding of color but also fosters a sense of community and healthy competition.

As this phase of the project concludes, the positive impact Chroma Harmony will have on promoting greater inclusivity within the gaming community and beyond is anticipated. The game's focus on accessibility and educational value positions it as a valuable tool for learning, particularly in the realms of color theory and inclusive gaming. Looking forward, Chroma Harmony presents opportunities for expanding inclusivity in digital entertainment and will play a role in shaping a more inclusive future for the gaming industry.

Acknowledgements

This work was developed at the research group GILT from IPP/ISEP, with the support of FCT/MCTES (UIDB/05627/2020, UIDB/05627/2020, 950/2019)

References

Carvalho, C. V., & Coelho, A. (2022). “Game-Based Learning, Gamification in Education, and Serious Games”. *Computers*, pp. 1–4.

Escudeiro, P., & Bidarra, J. (2008). “Quantitative Evaluation Framework (QEF)”. *Revista Ibérica de Sistemas e Tecnologias de Informação*, pp. 16–27.

Escudeiro, P., & Escudeiro, N. (2012). “Evaluation of Serious Games in Mobile Platforms with QEF: QEF (Quantitative Evaluation Framework”. *Proceedings of the 2012 IEEE Seventh International Conference on Wireless, Mobile and Ubiquitous Technology in Education*, pp. 268–271. IEEE. https://doi.org/10.1109/WMUTE.2012.65

Escudeiro, P., & Escudeiro, N. (2013). “Evaluating educational games in mobile platforms”. *International Journal of Mobile Learning and Organisation*, pp. 14–28. https://doi.org/10.1504/IJMLO.2013.051571

Escudeiro, P., Esdras, D., Galasso, B., Neto, N., & Costa, F. (2022). “Inclusive digital learning through serious games: A clipping for inclusion”. *Athena Research Book*. University of Maribor. DOI:10.18690/um.3.2022.8.

Escudeiro, P., Escudeiro, N., Oliveira, P., & Barbosa, M. (2017). "Blind's inclusion in mobile games". *2017 27th EAEEIE Annual Conference (EAEEIE)*, pp. 1–6. DOI:10.1109/EAEEIE.2017.8768494.

Escudeiro, P. M., Escudeiro, N. F., Reis, R. M., Barata, A., & Vieira, R. (2013). "Quality criteria for educational games". *EAI Endorsed Transactions on Game Based Learning*, 13. DOI:10.4108/trans.gbl.01-06.2013.e3.

Jayalath, J., & Esichaikul, V. (2020). "Gamification to enhance motivation and engagement in blended e-learning for technical and vocational education and training". *Technology, Knowledge and Learning*. DOI:10.1007/s10758-020-09466-2.

Marques, B. P., Barata, A., Carvalho, P., Silva, A., Queirós, P., & Escudeiro, P. (2018). "Applying the quantitative evaluation framework model for ensuring the MOOC quality". *International Conference e-Learning 2018*. ISBN: 978-989-8533-78-4.

Marques, B., Escudeiro, P., Barata, A., Carvalho, P., de Sousa, A., & Queirós, P. (2019). "Assistive technology applied in an inclusive MOOC for the blind". *Proceedings of the 11th International Conference on Computer Supported Education (CSEDU 2019)*, pp. 100–110. DOI:10.5220/0007724901000110.

Molina-Carmona, R., & Llorens-Largo, F. (2020). "Gamification and advanced technology to enhance motivation in education". *Informatics*, 7(2), 20. DOI:10.3390/informatics7020020.

Oostendorp, H. v., van der Spek, E. D. & Linssen, J. (2014). Adapting the Complexity Level of a Serious Game to the Proficiency of Players. EAI Endorsed Transactions on Serious Games, 1(2), pp. 1-8.

Verma, G. K. (2016). "Education and social integration for all: Challenges and responses". *Approaches to Educational and Social Inclusion*, pp. 9–21. Routledge.