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Using design principles as a lens to interpret user needs: a case study using a new 3D tic-tac-toe game

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ABSTRACT: This study investigates user engagement and its relationship with the visual aspects of design using a newly designed 3D Tic-Tac-Toe. The research examines user experience factors like cognitive engagement, fun, stress relief, etc., and to analyze their correlation with the design principles found in literature, such as Contrast, Framing, and Balance. 15 teams, comprising 2 players each, from design academic backgrounds, were provided with the game board to play. Researchers observed interactions and challenges, while subsequent surveys captured experience, aesthetics, emotional response, and design principles. The findings reveal the strong and weak correlations amongst the factors and the principles, highlights further prototype refinement. The insights integrate cognitive and emotional dimensions with core principles of design to create engaging and visually satisfying products.

KEYWORDS: design cognition, visualisation, creativity, patterns, principles of design

1. Introduction

Games have always been an integral part of human culture, serving as tools for entertainment, social interaction, and education. They provide structured environments where individuals engage in rule-based scenarios, fostering skill development, strategic thinking, and cognitive engagement. In modern society, where technology-driven learning is increasingly valued, games have emerged as essential educational tools, offering benefits in both physical and digital formats (Vlachopoulos & Makri, 2017; Atanasova, 2024). Historically, games have contributed to cultural exchange, socialization, and cognitive development by providing interactive spaces for experimentation, learning, and growth. Educational games have demonstrated potential in fostering critical thinking, memory retention, and social skills, equipping individuals to navigate complex real-world challenges (Atanasova, 2024; Naidoo, 2023). Indoor games, including board and digital formats, emphasize cognitive engagement within controlled environments. Research supports their role in promoting active learning by minimizing distractions and allowing players to focus entirely on game mechanics and objectives. Digital game-based learning (DGBL) is particularly effective in educational settings, boosting motivation, retention, and participation (Vlachopoulos & Makri, 2017). Additionally, indoor games enhance fine motor skills, spatial reasoning, and strategic thinking, offering cognitive benefits that extend beyond traditional learning approaches (Zhang & Zurlo, 2021).

Games offer significant educational and emotional benefits. Mathematical games, for example, reinforce logical reasoning, analytical skills, and problem-solving abilities, making them invaluable in academic settings (Naidoo, 2023). They create a safe environment for learners to experiment, refine strategies, and learn from mistakes without fear of failure (Vondrová & Šilhánová, 2013). Multiplayer games further enhance these benefits by fostering collaboration, teamwork, and communication. Such interactions promote social growth, helping players develop interpersonal skills and build group cohesion (Zhang & Zurlo, 2021; Atanasova, 2024). In educational settings, games align with design thinking by providing structured yet flexible environments for exploring ideas, testing strategies, and adapting to feedback. The

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variety of game types, ranging from strategy-based challenges to role-playing simulations, caters to diverse learning styles and preferences (Mashchenko, 2024). This versatility makes games an invaluable tool for fostering creativity and innovation.

Games play a pivotal role in shaping decision-making processes by offering structured scenarios where players must evaluate choices, anticipate consequences, and adapt strategies. Repetitive play fosters strategic thinking, a critical skill for effective decision-making. For instance, mathematical games challenge players to analyze outcomes based on sequential moves, enhancing their ability to make informed decisions under constraints (Vondrová & Šilhánová, 2013). Similarly, fuzzy matrix games allow players to navigate scenarios with imprecise information, equipping them to manage ambiguity and assess probabilities (Mashchenko, 2024; Seikh & Dutta, 2024). By blending structured objectives with engaging mechanics, games provide versatile platforms for learning, creativity, and growth. Whether used for education, recreation, or skill development, they remain indispensable tools for fostering innovation and adaptability in an ever-evolving world.

1.1. Tic-Tac-Toe: from 2D to 3D

Tic-Tac-Toe, a classic 2D paper and pencil game, while simple and intuitive, often leads to predictable outcomes due to its limited winning strategies (Garg et al., 2017). Variants like Ultimate Tic-Tac-Toe add complexity by introducing smaller grids and layered rules, requiring players to think strategically within a 2D framework (Baum, 1975). However, these versions still lack the strategic depth and engagement of contemporary board games. The 3D Tic-Tac-Toe variation introduces a new spatial dimension to the 2D configuration, as a 3x3x3 cube, with 27 playable spaces as compared to the 9 that the 2D version affords, allowing for multiple winning configurations across various planes on the cube. This design demands a higher level of cognition to engage with a 3D interface, dynamic strategy adjustments, and the application of fuzzy logic to navigate uncertainties in gameplay (Vahedi et al., 2023). In this version, players place balls within a cubic structure, aligning them horizontally, vertically, or diagonally across different layers. The flexibility of the void-based frame mirrors the dynamic nature of fuzzy matrix games, where strategies are less rigid, and outcomes depend on probabilistic decisions. Players alternate turns, balancing aggressive moves with defensive strategies to maximize their chances of winning while limiting their opponent's options. This creates a dynamic decision-making environment that engages both logical reasoning and spatial awareness.

1.1.1. Components of newly introduced 3D Tic-Tac-Toe game

The 3D Tic-Tac-Toe game features two primary components: the frame and the play pieces. The frame, a 3x3x3 cube with 27 voids as shown in figure 1, serves as the spatial foundation for gameplay. It is divided into three layers, each with nine voids, encouraging players to think across multiple dimensions. Constructed from durable materials like lightweight metal or plastic, the frame ensures stability and clarity, allowing players to identify available spaces with ease.

Complementing the frame, the play pieces are interactive markers that claim spaces within the voids. Differentiated by vibrant colors, these pieces enhance the tactile and visual experience while ensuring functionality. Designed for both stability and aesthetics, they fit securely into the voids, supporting dynamic and engaging gameplay.

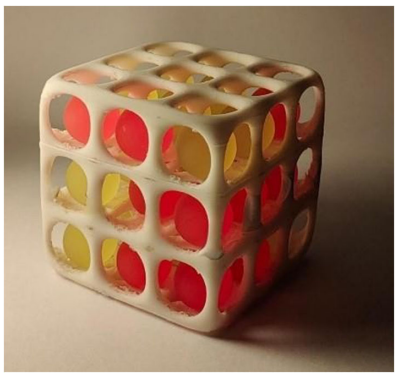


Figure 1. Void cubes filled with balls

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1.2. Design principles and engagement

Design principles serve as guidelines to develop the visual aspects of designing an artefact with intent, shaping the user's experience with the artefact, usually in the ways it can be perceived by the user. There are several design principles, these include, and are not limited to: 1. Balance, 2. Contrast, 3. Emphasis, 4. Framing, 5. Harmony, 6. Hierarchy, 7. Movement, 8. Proportion & Scale, 9. Repetition, 10. Rhythm, 11. Symmetry, 12. White Space (Johnson, M., 1995; Tersiisky, D., 2004; Adams, E., 2013; Chapman, C., 2018).

These principles may play critical roles in defining a game's visual and structural characteristics. Form relates to the physical shape of objects and how they occupy space, influencing player perspective and strategy. In a grid, this design transitions players from planar strategies to volumetric ones, enables an understanding of multi-level relationships and adjacencies (Wolfe, 2011). This shift aligns with Alexander's (1964) differentiation between habitual and intentional design, encouraging dynamic spatial awareness and strategic thinking (Maheu-Cadotte et al., 2020). Enhancing these experiences, elements such as color-coded markers and highlighted winning paths provide visual feedback, elevating cognitive engagement and motivation (Alfred et al., 2024). The integration of these principles may ensure that the design is both visually appealing and functionally effective.

The balance of shapes and colors within the game structure helps to create harmony and maintain user focus (Batchelder, 1908). Symmetry, particularly in a 3D layout, supports an intuitive spatial understanding, making the gameplay naturally accessible and cognitively satisfying (Lidwell et al., 2003). Contrast, using colors and textures, distinguishes player pieces and pathways, thereby aiding visual clarity and strategic gameplay (Tersiisky, 2004). Moreover, the principle of hierarchy guides the organization of the game board and its elements, ensuring that critical components like playable nodes are prominently emphasized while less important elements recede into the background (Johnson, 1995; Interaction Design Foundation, n.d.). This prioritization aligns with the cognitive needs of players, enhancing their decision-making and engagement with the game (Fu et al., 2016). Similarly, the principles of emphasis and repetition reinforce usability by highlighting critical aspects of the game while ensuring a sense of rhythm in the gameplay experience (JSTOR, 1995; Adams, 2013). In addition, considering how the principles of composition influence design ensures that both aesthetic and functional aspects align harmoniously, offering an immersive experience (Daily JSTOR, n.d.).

1.3. Research problem and motivation

Although the design of games has evolved rapidly over the years, most research focuses on 2D mechanics, leaving a significant gap in understanding how 3D spatial structures impact player perception and engagement. The move from 2D to 3D requires developing spatial reasoning, and adjust strategies dynamically. However, there is limited research on how design principles such as balance, contrast, and hierarchy affect usability, engagement, and emotional response.

The lack of empirical studies in this area limits the ability of designers to iterate the formal aspects of the design, based on feedback received on the user experience. This research intends to fill this gap by examining how these design principles shape player engagement and perception. Understanding these dynamics can lead to more immersive and effective game experiences, benefiting game designers, educators, and interactive product developers alike.

1.4. Research question

Based on our aforementioned problem we arrived at our research question:

How do compositional design principles contribute to user experience, emotional response, and engagement in a newly designed 3D Tic-Tac-Toe gameboard?

By addressing this question, we aim to reconcile the gap between visual design and user perception, providing insights for interpreting user experience, discovery of user needs, and future product development.

2. Experiment setup and execution

The experiment was conducted to evaluate the design principles applied in the 3D Tic-Tac-Toe game board through user interaction and feedback. A total of 30 designers, organized into 15 teams, engaged in gameplay sessions. Each team consisted of two players, collaborating to explore aspects of the design.

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The participant provided insights into the principles embedded in the design of the game board. After each gameplay session, participants were asked to complete a structured questionnaire designed to capture their perceptions, preferences, and overall experience with the game. The dual role of participants as users and designers allowed for a unique perspective on the efficacy of the design principles, blending direct interaction with reflective evaluation. The experiment's structure facilitated the game's comprehensive assessment of its experiential aspects, highlighting its strengths and areas for improvement.

2.1. Selection of key dimensions:

The study evaluates four primary dimensions:

Gaming Experience: Cognitive engagement, complexity, and fun.
Aesthetic Appeal: Visual clarity, material preferences, and attractiveness.
Emotional Aspect: Stress relief, enjoyment, and mood enhancement.
Principles of Design: The impact of the aforementioned design principles.

These dimensions were picked based on prior research (Johnson & Wiles, 2005; Fu et al., 2016), which highlights their role in shaping user experience in interactive environments.

2.2. Game rules and strategy

The gameplay of 3D Tic-Tac-Toe is designed for two players. The players are handed the frame and play pieces in 2 colours. The game begins with Player 1 placing their colored ball into any available space on the grid, including the center, followed by Player 2 making their move in an open spot of their choice. Players are free to place their balls anywhere in the cube, switching between sides without the need to complete one side before moving to another. The primary objective is to form as many straight lines of three as possible in one color, spanning across all six sides, while simultaneously blocking the opponent's attempts to do the same. Straight lines can be horizontal, vertical, or diagonal; however, lines formed using the center spot are only valid along the X, Y, or Z axes, excluding diagonal configurations. The winner is determined by counting the total number of straight lines each player has created by the end of the game. For example, if one player forms six lines while the other forms nine, the latter is declared the winner.

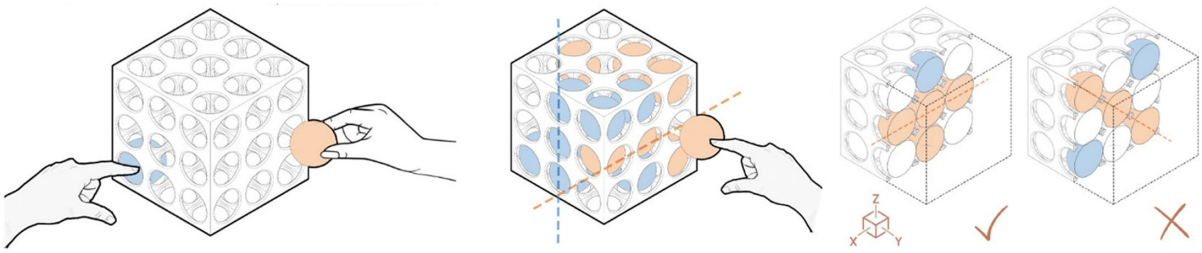


Figure 2. Game strategy

2.3. Questionnaire design and refinement

Based on the dimensions selected, the questionnaire prepared included several factors: stress relief, fun, complexity, engagement, gameplay time, competitiveness, and mood. These were chosen to evaluate the holistic experience of playing the game. Prior research (Ng et.al, 2012) highlighted that stress relief and fun were the important to understand the games' ability to provide a relaxing yet stimulating environment to players. An affective design fosters emotional engagement and user satisfaction. The cognitive factor introduced in this game survey aligns with the findings that interactive design stimulates critical thinking and maintains player interest (Gao et al.,2025). This aligns with Csikszentmihalyi's flow theory that games are successful when they are designed to generate positive effects and facilitate the concept of flow. Flow is a state of concentration, deep enjoyment, and total absorption in an activity (Johnson and Wiles, 2005; Norman, 2004; Khalid, 2006). Engagement as a factor was considered for the survey to analyze teams' productivity, collaboration dynamics, and overall workplace satisfaction (Salazar-Cardona, 2024). The emotional factors were assessed on a Likert scale (Cheng et al., 2021). To assess the

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aesthetic appeal of the game board, we formulated the questions shown in Fig. 3, based on the idea that aesthetics influence user satisfaction and emotional engagement (Norman, D.A., 2004).
Lastly, the questionnaire included the influence of principles of design- how it influenced the gameplay and if/how it enhanced the perceptual qualities of the game board.

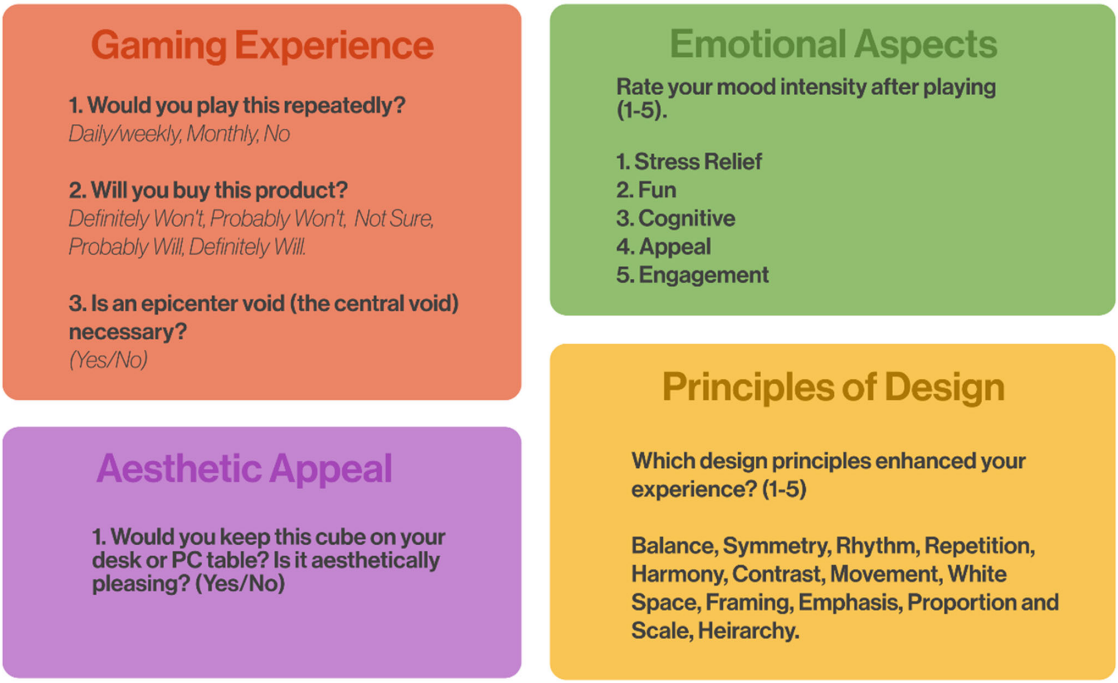


Figure 3. Questionnaire

3. Results and discussion

3.1. Survey results

The survey results reflect a strong overall approval of the game, highlighting its cognitive engagement (average rating: 4.08), fun (4.00), and overall engagement (4.15) as standout aspects. Respondents largely appreciated the cube's size, with 75% finding it "just right" for gameplay, and 91.7% agreed it is aesthetically pleasing enough to keep on a desk or PC table. The game's appeal to be replayed also stood out, with 58.3% indicating they would play daily or weekly. Preferences for frame and ball materials favored a hard frame with soft balls (66.7%), suggesting a balanced tactile experience. A significant majority (75%) emphasized the necessity of a central void, reinforcing its importance in gameplay. White and red were the most appealing colors during gameplay, with white leading at 50%. Design principles like symmetry (61.5%) and visual elements such as color (69.2%) were noted as key contributors to an enjoyable experience. However, aspects like stress relief (3.50) and appeal (3.46) were rated slightly lower, pointing to potential areas for improvement. These results suggest that while the game excels in engagement and aesthetics, there is room for enhancements to further elevate its stress-relief and visual appeal aspects. The survey also explored preferences for alternative frame structures, where the polyhedron design stood out as the most popular choice, preferred by 58.3% of respondents, followed by the sphere (33.3%). The importance of design principles like framing and proportion & scale (38.5% each) suggests that respondents valued balance in the game's aesthetics. Additionally, visual elements such as space (53.8%) and line (53.8%) contributed significantly to the gameplay experience. Respondents' willingness to purchase (66.7% "probably will") highlights its potential market appeal, though refining stress-relief features could broaden its audience. The game demonstrates a clear ability to engage users cognitively and visually, making it well-suited for further development and customization to align with diverse user preferences.

3.2. Comprehensive analysis

The analysis reveals key trends and actionable insights for enhancing user experience. High scores were observed in Cognitive (average 4.08) and Engagement (average 4.15), highlighting that users find the game

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mentally stimulating and immersive. However, Fun scored moderately at 4.0, indicating general enjoyment without overwhelming enthusiasm, while Stress Relief (3.5) and Appeal (3.46) suggest areas needing improvement, particularly in relaxation and visual appeal. Pearson Correlation coefficient (r) (Schober et al., 2018) as shown in Figure 4 provides that insights emphasize strong positive relationships, such as between Engagement and Fun ($r \approx 0.67$), indicating that mentally stimulating games are perceived as more enjoyable. Similarly, Engagement and Appeal correlated positively with ($r \approx 0.07$), underscoring the influence of gameplay immersion and aesthetic quality on user satisfaction. Conversely, Stress Relief showed weak correlations with other metrics, suggesting it operates independently in the user experience framework.

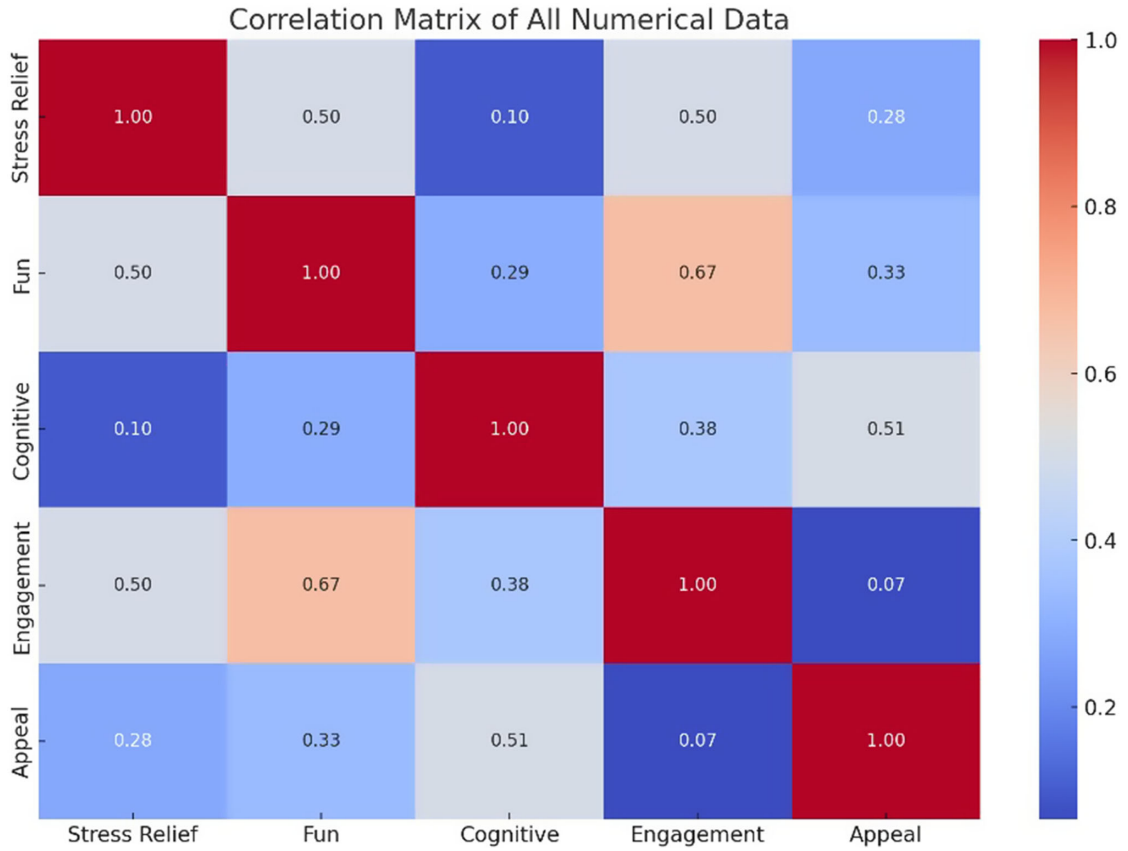


Figure 4. Correlation matrix of factors

User segmentation revealed distinct preferences: Frequent players (Daily/Weekly) rated Engagement and Fun higher, valuing strategy, while Occasional players (Monthly) scored lower on Stress Relief and Appeal, signalling a need for enhanced relaxation to retain this group. Underperforming areas include Stress Relief, where lower scores highlight a mismatch between game design and relaxation. Similarly, moderate Appeal scores suggest the need for customizable and visually engaging designs to enhance attractiveness.

As represented in figure 5, Users who highlighted Balance and Framing as key principles tended to rate Appeal and Engagement higher, suggesting that emphasizing these principles could enhance the user experience. Users mentioning Contrast often rated Fun higher, indicating that clear visual differentiation contributes positively to enjoyment. The most frequently mentioned design principles include Contrast, Framing, and Balance, which emerged as key contributors to an engaging experience. Participants appreciated Contrast for its ability to highlight elements effectively, making gameplay more visually appealing. Framing was noted for providing structure and focus, enhancing spatial clarity. Despite being impactful, Balance, while well-rated, appears less recognized compared to other principles. Its potential lies in creating a harmonious and aesthetically pleasing environment, could be further emphasized.

3.3. Observations during the playing sessions

Players faced several notable challenges while engaging with the 3D Tic-Tac-Toe game. Spatial awareness and depth perception emerged as a significant hurdle, with many struggling to visualize and

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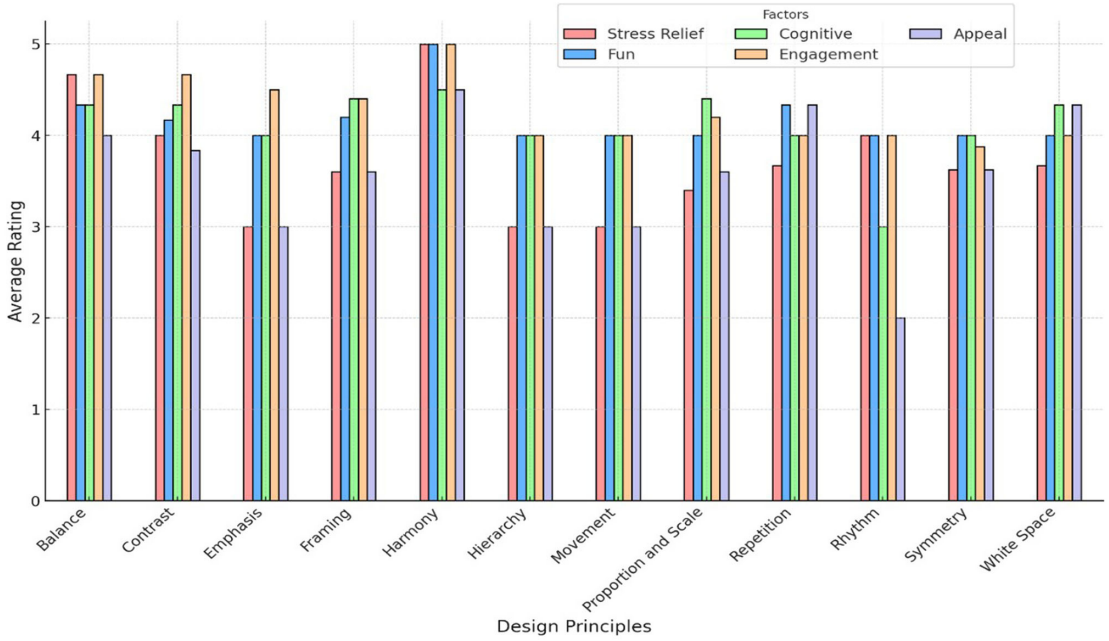


Figure 5. Bar graph for average rating of factors v/s design principles

interact with the multi-layered grid. Hesitation and pauses indicated difficulty in tracking moves across layers, especially for new players, which slowed gameplay and reduced enjoyment. Incorporating visual aids, such as highlighted paths or translucent layers, could possibly enhance spatial awareness and streamline interactions. Strategy development was another challenge, as players often focused on individual layers rather than utilizing the full 3D structure, overlooking opportunities for diagonal or vertical wins. A tutorial or gameplay hints showcasing advanced strategies, like cross-layer connections, could help players think more comprehensively. Physical interaction with the 3D frame also posed difficulties. Players occasionally struggled to place markers accurately, leading to minor disruptions in gameplay. Improving the frame's design to ensure stability and clear boundaries for slots would facilitate smoother play. Additionally, the game introduced a high cognitive load, as players had to monitor multiple layers simultaneously, causing confusion and fatigue. Offering a "focus mode" that simplifies visible grids to specific layers could help reduce mental strain and keep the game appealing to casual players. Uneven game flow and turn timing was another issue, with extended pauses between moves disrupting the dynamic of the game. Introducing a turning timer could maintain a steady pace and enhance the competitive aspect. Lastly, user familiarity was a challenge, especially for first-time players who required frequent clarifications and struggled to adapt to the mechanics. Providing a quick start guide or visual aids with example moves could lower the learning curve and encourage replay ability. Addressing these challenges through thoughtful design adjustments and user-centric features can significantly elevate the overall gaming experience.

4. Conclusion

The findings of the study of the 3D Tic-Tac-Toe game illustrate the connection between user experience factors and the principles of design, emphasizing its strong correlations and areas for possible refinement. The survey results and playing session observations reveal that the game excels in engaging users cognitively and visually, with its reported adequate size, aesthetically pleasing design and its repeated playability being key strengths. High ratings for cognitive engagement and fun, coupled with positive correlations between gameplay immersion and satisfaction, validate the game's potential to foster meaningful user interactions. Nevertheless, the findings identify critical opportunities for refinement, as lower ratings for stress relief and appeal underscore the importance of incorporating targeted enhancements. The analysis positions key design principles- Harmony, Contrast and Balance as essential drivers of user satisfaction in this research. These insights validate the role of design principles in enhancing functionality, aesthetic quality, and emotional engagement. By translating user insights into design principles, this research provides an approach for designers to iteratively refine prototypes,

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ensuring alignment with user preferences and visual expectations. The findings reaffirm the importance of integrating empirically validated design principles into the development process, enabling prototypes to achieve greater aesthetic resonance and functional success. This approach highlights the value of combining cognitive and sensory engagement with design principles to create visually compelling and user-centered designs. The interplay of design principles observed in this study is not limited to games. These findings can be extended to other domains, such as educational tools, simulation-based training, and digital therapeutic applications, where enhancing user engagement and emotional well-being is critical. By applying the same design frameworks, developers can create more immersive, intuitive, and supportive interactive systems across a variety of contexts.

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