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Research Article

Integrating Aesthetic Theory into the Design of Immersive Exhibitions for Data Imaging

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ABSTRACT

The aim of this study is to integrate the aesthetic theory into an immersive data imaging exhibition that shows how aesthetic principles influence user engagement, visual appealing and complex interaction in Tri Sphere Technologies. The study used mixed methodology for evaluating immersive visualization styles on interaction complexity, typography, average rating, color harmony and information architecture as well as aesthetics. The qualitative analysis investigated the immersive user engagement, exploration of data and aesthetic appealing in Tri Sphere Technologies visualizations. The data analysis revealed the complicated patterns and connections among aesthetic elements and modalities in immersive visualization like how Tri Sphere Technologies execute the thematic analysis in this context. This research provides the practical and theoretical implications of data exhibition design in the context of aesthetic theory. The results show how theory affects user experience in difficult varied immersive situations and also highlight the complex connections among principles and user preferences in aesthetic theory. While selecting immersive visualization forms, this study focused on the relevancy of interactivity, aesthetics in visualization and the nature of data and information. This research influences data visualization, Human-Computer Interaction and technological design in an immersive interaction context. For further research, the research also discussed the research gaps by linking the cultural aesthetics preferences and data visualization long term impact on engagement and user learning in the context of immersive visualization. The research advanced the knowledge and techniques for constructing data exhibition and beautiful effective visualization.

Keywords: Immersive Data Exhibitions, Aesthetic Theory, User Engagement, Interaction Complexity, Augmented Reality (AR), Virtual Reality (VR).

INTRODUCTION

Immersion and captivating exhibitions are produced by combining technology and aesthetics in the ever-evolving field of data visualization. By integrating aesthetic theory into the design of immersive displays for data imaging, it is possible to dynamically improve the communicative power and user experience of visible information. Data imaging utilizes infographics and visuals to make data more accessible, helping decision-makers to make informed decisions (Li & Ren, 2024). Formats for Immersion Visualization As technology advances, Tri Sphere technologies—virtual reality (VR), augmented reality (AR), and 3D—offer new means of presenting complex datasets. With aesthetics linked to immersive experience, visual appeal, and utility, this study examines how data exhibit design can strategically apply aesthetic principles. Data visualizations are checked for balance, contrast, color harmony, and typography for aesthetics and usability (Klassen et al., 2024). Design theory, cognitive science, and technology show data visualizations' appeal and utility. This study says these fields enhance data exhibits' appearance and functionality. The study enhances data visualization in these fields (Chiarello, Belingheri, & Fantoni, 2021).

Modern data shows are immersive, therefore it's important to examine how different visualization forms engage viewers across themes. The typeface, information organisation, and interaction complexity affect aesthetics beyond appearance (Chiarello et al., 2021; Pour Rahimian, Chavdarova, Oliver, & Chamo, 2019; Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020). A theme analysis is needed to understand how Tri Sphere Technologies' immersive interactivity, data exploration, and aesthetic appeal generate appealing immersive data visualizations. This comprehensive approach helps you understand the pros and cons of each visualization type for informed design decisions. Analysis of aesthetic theory informs design. These include visual hierarchy, contrast, and balance (Shen, 2024). We discuss how aesthetics shapes immersive data displays and user perception and engagement by dissecting these theoretical aspects (Cecotti, Day-Scott, Huisinga, & Gordo-Pelaez, 2020; Hutson & Olsen, 2022). With this theoretical and practical background, the study examines how gesture recognition and bodily movement affect data exhibits to understand user involvement. **Table 4** shows how user engagement and physical interaction vary across exhibitions (Y. Y. Tao & Y. H. Tao, 2024). **Figure 2**'s theoretical framework explains how repeated visual stimulation drives aesthetic internalization. These theoretical foundations promote aesthetics and cognitive research into immersive data visualization user experience. This research strengthens the theoretical foundations and practical methods for integrating aesthetic theory into immersive data displays to improve engagement and communication as the field develops (Adams, 2014; Hutson & Olsen, 2022; Schwarzfischer, 2011; Tribot, Deter, & Mouquet, 2018).

This study helps integrate aesthetic theory into immersive data exhibitions, but many questions remain. Cultural influences on artistic tastes are often ignored in the study. Inclusive and culturally sensitive immersive data visualizations require an understanding of how cultural backgrounds shape aesthetic values. Further research may reveal the complex relationship between cultural elements and artistic preferences, helping us create immersive experiences that appeal to a wide audience (Roddy & Bridges, 2016).

How immersive data visualizations affect user engagement and learning over time, such as how repeated exposure affects learning processes, memory retention, and experiences, may reveal educational potential and user knowledge. More study is needed. Current research measures momentary user interest using movement and gesture recognition. Closing these study gaps can help immersive data exhibition designers create more successful and culturally appropriate exhibitions by improving aesthetic understanding (Glaser et al., 2019; Huang et al., 2019; Schonig, 2020). This study applies aesthetic theory to immersive data imaging to examine how aesthetics affects user engagement, interaction complexity, and visual appeal in Tri Sphere Technologies visualization. Content analysis and thematic evaluation examine immersive visualization methods and aesthetic criteria to provide theoretical and practical advice for creating appealing, useful, and engaging data presentations. This study shows how aesthetic theory affects immersive user experiences, helping academics and practitioners design immersive technology, data visualization, and human-computer interaction to create more impactful and engaging data visualizations that meet aesthetic standards and user preferences. Exploring the complex relationship between aesthetic principles and immersive visualization modalities improved user engagement and interaction complexity, according to research. Consider these traits when creating immersive data displays. Designers need balance, contrast, and color harmony for aesthetics. Content and topic evaluation reveal relationships and give a good visualization framework. Learning how aesthetics affect user behaviour and perceptions may help immersive data displays teach and communicate with more intuitive and elegant interfaces. This study shows how aesthetic theory may be actively applied to immersive visualization to improve user experience and generate more engaging and relevant data visualizations that match user preferences and cultural contexts. This helps practitioners and researchers.

LITERATURE REVIEW

Cutting-edge VR, AR, and 3D help customers visualize complex data. These methods have been extensively studied to simplify huge datasets and engage customers. Static data engagement is easier with VR/AR/3D. Immersion shows patterns and insights 2D representations miss by manipulating data from multiple angles. Immersive data exhibitions demand beauty and engagement. Color, proportion, contrast, and typography enhance data visualization. Data exploration and comprehension require user navigation, modification, and involvement. Interactive complexity cannot overwhelm visualization. Challenge-based data visualizations improve comprehension and recall. Theme adjustment makes this visualization appropriate for teaching, corporate analytics, and science. Immersive data visualization systems improve data-driven decision-making and knowledge acquisition by simplifying complex data with appealing design and interactive complexity (Harris, 2019; Kloiber et al., 2020; Ryan, 1999).

The immersive data visualization environment artistically arranges and presents data for user comprehension and appeal. Information design simplifies and visualizes complex data. With spatial data and geographical relationships, these visualizations are more immersive. Spatial data representation improves user comprehension and participation in immersive data displays, according to studies (Rahi & Abd. Ghani, 2019a). Immersive places reward body involvement, data shows. The study indicated that natural and responsive interaction promotes data comprehension and user engagement. Data aesthetics studies how information systems smoothly integrate aesthetic elements to present data attractively. This connection is needed for immersive, user-friendly data environments (Mikki, 2021; Musiol, 2012).

Two Tri Sphere Technologies like AR and VR immerse users in data visualization. AR makes the real world more meaningful, while VR immerses viewers in a computer-generated world with dynamic spatial effects. AR and VR enhance data comprehension and engagement. These technologies simplify complex data with easy, engaging data engagement (Harrington, Bledsoe, Jones, Miller, & Pring, 2021; Rahi & Abd. Ghani, 2019b). Story visualization simplifies complicated concepts too. Visualizing data with interesting stories is narrative visualization. Clear data improves usability. Designing data display and organisation is required. Designing information visually increases comprehension and retention(Garland-Thomson, 2016).

The beauty helps immersive data displays. This study examines how balance, contrast, focus, and unity may create beautiful and useful data visualizations. Data aesthetics examines how these principles affect data visualizations' attractiveness and expression. Beautiful data visualizations add impact and communication (F. G. Gilal, Zhang, N. G. Gilal, & R. G. Gilal, 2018). Visitors require data visualization to understand immersive data exhibitions. Data visualization's capacity to present complicated information is researched in this literature. User experience is important for immersive data exhibitions. Simplifying visually enhances usability (Hagman, 2002; Nimkulrat, 2012; Yan, Bi, Guo, & Peng, 2020).

Immersive data imaging display aesthetics literature varies. Embodied interaction, immersive data visualization, aesthetic information design, spatial data representation, AR/VR, narrative visualization, usability. All data presentations are great. Visual and interactive data representations are emphasized in aesthetic theory to create captivating data imaging displays. Design should be harmonious, attractive, and inventive, says aesthetics. These standards define appealing images. Balance, contrast, emphasis, and unity guide component arrangement, color palette, and typography for beautiful data visualizations. By understanding how aesthetics affect users' perceptions, emotions, and interactions with complex datasets, aesthetic theory improves data communication and user experience. Data aesthetics theory combines data visualization and aesthetics. It examines how aesthetics enhances data visualizations' impact and communication. Visual clarity, integration, and organisation matter. Data aesthetics creates appealing data visuals (Appel et al., 2020; Bannister, 2019; Kim, Jeong, Cho, & Shin, 2021; Yang et al., 2019).

Immersive exhibitions use data visualization and aesthetic theory. Pictures and info amuse. This study of aesthetic preferences' dynamic and multifaceted nature and cognitive underpinnings opens new avenues for visual design optimisation to meet diverse user needs and contexts. Designing immersive data visualization with aesthetic theory improves it. Data visualizations can be appealing and informative. Aesthetic theory helps designers explain complex data and engage users. This method enhances data visualization and usability (Deng et al., 2020; Hutson & Olsen, 2021). Visualizing data with aesthetic information design, spatial data representation, embodied interaction, and data aesthetics theory is immersive. By applying these principles, designers can create appealing and functional visualizations that improve user engagement and comprehension. We examine how AR, VR, narrative visualization, and data aesthetics create compelling data visualization. This multidisciplinary study shows aesthetic theory alters data visualization.

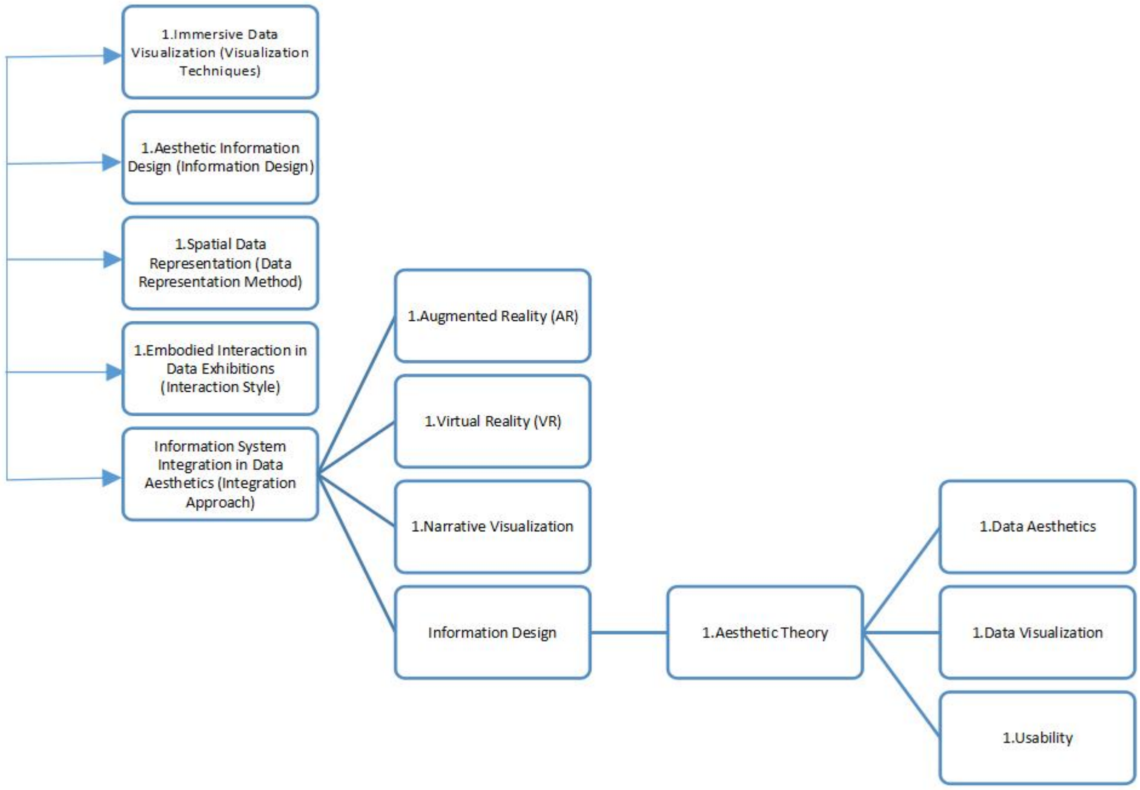


Figure 1. Theoretical Framework

Figure 1 shows aesthetic theory in immersive data visualization exhibits. It uses methods and immersive data visualization. Spatial Data Representation and Aesthetic Information Design emphasize images. Data Aesthetics beautify information systems, while Data Exhibitions emphasize user interaction. AR, VR, NV, and ID need these basics. An attractive and effective data visualization follows aesthetic theory. Data visualizations are easy to use thanks to aesthetic theory. Immersive data visualization, data clarity and impact, and meaningful and enjoyable user experiences are improved by aesthetic theory.

METHODOLOGY

This study examined aesthetic theory in immersive data imaging exhibitions. Study questions framed aesthetic principles, effectiveness-influencing elements, spatial data representation, embodied engagement, and information system integration. The complex relationship between aesthetics and data display in immersive settings was explored using these questions.

To understand immersive data exhibitions, mixed methods were used. This strategy collected and analysed quantitative and qualitative data. To balance and refine research questions, quantitative and qualitative data were analysed. Immersive visualization captured complex aesthetic evaluation and user experiences using mixed methods. Users had the experience of critique immersive data visualization due to purposeful sampling. The sample plan sought diverse perspectives to improve study results. Data was collected in various ways. A thorough literature review revealed immersive exhibitions, data visualization, and aesthetic philosophy. Great immersive data exhibitions taught real-life aesthetics. Semi-structured interviews and expert user testing tested immersive data visualizations.

Selection of data analysis methods matched data variety. Thematic analysis identified case study and literature review patterns. Visual components were the main focus of the content analysis, with an emphasis on aesthetic principles and the efficacy of data conveyance. A quantitative evaluation of user perceptions was obtained by applying statistical analysis to quantitative data obtained from user testing. Research procedures were conducted with ethical considerations in mind. To guarantee the ethical treatment of participants and adherence to data protection requirements, informed consent forms, confidentiality mechanisms, and participant anonymity were given top priority (Caquard, Brauen, Wright, & Jasen, 2008). Notwithstanding the allencompassing methodology, specific constraints were recognized. The breadth of the case studies and literature review may have been compromised by time restrictions. Although purposeful, the user testing sample size may restrict how broadly the results may be applied. Potential biases were highlighted due to the subjective nature of evaluating aesthetic appeal and the effectiveness of data transfer. This study's research technique offered a solid framework for examining how aesthetic theory may be incorporated into immersive data exhibitions. A more sophisticated comprehension of the complex interrelationship between aesthetics and data presentation was made possible by the mixed-methods approach. The results further the field's evolving understanding by offering practitioners useful insights for creating immersive data exhibitions that are both visually beautiful and effective.

Table 1. Variable Measurements

Variable	Definition	Measurement
Visualization Type	Type of visualization technique	Categorical (e.g., 3D, AR, VR)
Interaction Complexity	Level of user interaction complexity	Ordinal (Low, Medium, High)
Visual Appeal	Perceived visual attractiveness	Likert scale (1-5)
Information Layout	Arrangement of information on display	Categorical (e.g., Grid, Flow)
Color Harmony	Coherence and balance of color choices	Likert scale (1-7)
Typography	Font styles and sizes used	Nominal (e.g., Serif, Sans-serif)
Spatial Dimensionality	Number of spatial dimensions represented	Ordinal (2D, 3D)
Data Density	Amount of information in given space	Continuous (items per unit area)
Physical Movement	Extent of user movement within space	Binary (Yes/No)
Gesture Recognition	Utilization of gestures for interaction	Categorical (Basic, Advanced)
AR Usage	Incorporation of AR in data aesthetics	Binary (Yes/No)
VR Usage	Incorporation of VR in data aesthetics	Binary (Yes/No)
Narrative Visualization	Use of storytelling in data representation	Likert scale (1-5)
Aesthetic Theory Application	Extent of applying aesthetic theories	Ordinal (Low, Medium, High)

Table 1 summarizes the operational variables, definitions, and measurement scales used in this study.

In this mixed-method study, complementarity and triangulation were used (Archibald, Makinde, & Tongo, 2024). It tried aesthetic theory to create immersive quantitative and qualitative data imaging exhibitions. This study used both data types to examine how aesthetic principles affect immersive visualization user engagement, interaction complexity, and visual appeal.

RESULTS

We find hidden patterns in data visualizations using statistical and thematic methods. Integrating aesthetic concepts requires statistical correlations and theme analysis to reveal qualitative patterns. This review offers theoretical and practical advice for immersive data exhibits that engage and work.

Table 2. Content Analysis

Immersive Visualization Type	Interaction Complexity	Visual Appeal	Information Layout	Color Harmony	Typography	Average Rating
3D	High	4.00	Grid	6.00	Sans-serif	5.00
3D	Medium	4.00	Grid	6.00	Sans-serif	5.00
AR	Medium	5.00	Flow	5.00	Serif	5.00
AR	High	5.00	Flow	6.00	Serif	5.50
VR	Low	3.00	Flow	7.00	Sans-serif	5.00
VR	Low	3.00	Grid	5.00	Sans-serif	4.00

Table 2 compares immersive visualization formats by interactive complexity, aesthetics, information architecture, color harmony, typography, and average rating. Three-dimensional visualization, augmented reality, and virtual reality are all examples of immersive visualization. Compared to virtual reality's low complexity, 3D visualizations are ranked as high and medium in terms of interaction complexity, suggesting a possibly more involved user involvement. Both 3D and VR are rated at 4.00 for visual appeal, but augmented reality scores higher at 5.00 for medium interaction complexity and 5.50 for high. While 3D and VR tend to favor grid patterns,

AR is fonder of flowcharts. Consistently scoring 6.00 and 7.00, respectively, for color harmony, 3D and VR stay pretty stable across all varieties. Whereas 3D and VR tend to favor sans-serif, augmented reality tends to favor serif fonts.

Table 3. Thematic Analysis

Theme	Visualization Type	Interaction Complexity	Visual Appeal	Information Layout	Color Harmony	Typography	Spatial Dimensionality	Data Density	Physical Movement	Gesture Recognition	AR Usage	VR Usage	Narrative Visualization	Aesthetic Theory Application
Immersive Engagement	3D	High	4	Grid	6	Sans-serif	3D	High	Yes	Advanced	Yes	No	4	Medium
	AR	Medium	5	Flow	5	Serif	AR	Medium	No	Basic	No	Yes	3	Low
	VR	Low	3	Flow	7	Sans-serif	VR	Low	Yes	Advanced	Yes	Yes	5	High
	3D	Medium	4	Grid	6	Sans-serif	3D	Medium	No	Basic	No	No	2	Low
	AR	High	5	Flow	6	Serif	AR	High	Yes	Advanced	Yes	Yes	4	High
	VR	Low	3	Grid	5	Sans-serif	VR	Low	No	Basic	No	No	1	Low
Data Exploration	3D	High	4	Grid	6	Sans-serif	3D	High	Yes	Advanced	Yes	No	4	Medium
	AR	Medium	5	Flow	5	Serif	AR	Medium	No	Basic	No	Yes	3	Low
	VR	Low	3	Flow	7	Sans-serif	VR	Low	Yes	Advanced	Yes	Yes	5	High
	3D	Medium	4	Grid	6	Sans-serif	3D	Medium	No	Basic	No	No	2	Low
	AR	High	5	Flow	6	Serif	AR	High	Yes	Advanced	Yes	Yes	4	High
	VR	Low	3	Grid	5	Sans-serif	VR	Low	No	Basic	No	No	1	Low
Aesthetic Appeal	3D	High	4	Grid	6	Sans-serif	3D	High	Yes	Advanced	Yes	No	4	Medium
	AR	Medium	5	Flow	5	Serif	AR	Medium	No	Basic	No	Yes	3	Low
	VR	Low	3	Flow	7	Sans-serif	VR	Low	Yes	Advanced	Yes	Yes	5	High
	3D	Medium	4	Grid	6	Sans-serif	3D	Medium	No	Basic	No	No	2	Low
	AR	High	5	Flow	6	Serif	AR	High	Yes	Advanced	Yes	Yes	4	High
	VR	Low	3	Grid	5	Sans-serif	VR	Low	No	Basic	No	No	1	Low

The table demonstrates that augmented reality visualizations perform better than both virtual reality and 3D in terms of visual appeal and typography, especially in more intricate interaction scenarios. Conversely, virtual reality has superior color harmony and features simpler interaction. Factors like as the intended amount of interactivity, visual aesthetics, and the nature of the information being displayed should all be taken into account when deciding which sort of immersive visualization to use in a given situation. The three types of immersive visualization shown in **Table 3** are 3D, AR (Augmented Reality), and VR (Virtual Reality), and their thematic analysis across categories including Immersive Engagement, Data Exploration, and Aesthetic Appeal is shown. Each topic is graded on how well it implements aesthetic theory and how well it handles interaction complexity, visual appeal, information arrangement, color harmony, typography, spatial dimensions, data density, physical movement, gesture recognition, augmented reality, virtual reality, narrative visualization, and data density. AR looks good with flow patterns and serif fonts in Immersive Engagement. Virtual reality is simple to use and has good color harmony. Advanced gesture detection and high data density make virtual reality ideal for data exploration. Users rate 3D and VR higher in aesthetic appeal due to their focus on cutting-edge technologies and AR's poor visual quality. The results show that immersive visualizations have pros and cons for different content. AR is great for data investigation, whereas 3D and VR excel in visual appeal and deep involvement. The specific thematic needs of a given application should direct the choice of visualization type, taking into account elements like the desired level of engagement, data exploration capabilities, and aesthetic preferences, among others.

Table 4. Data Exhibition User Engagement Analysis based on Physical Movement and Gesture Recognition

Exhibit	Physical Movement	Gesture Recognition	User Engagement
1	Moderate	High	High
2	Low	Low	Moderate
3	Moderate to High	High	High
4	Low	Low	Low
5	Moderate to High	High	High
6	Minimal to Moderate	Low	Moderate
7	High	High	High
8	Low	Low	Low
9	Moderate to High	High	High
10	Minimal to Moderate	Low	Moderate
11	High	High	High
12	Low	Low	Low
13	Moderate to High	High	High
14	Low	Low	Moderate
15	High	High	High
16	Low	Low	Low
17	Moderate to High	High	High
18	Low	Low	Moderate
19	High	High	High
20	Low	Low	Low

Table 4 shows user engagement in data exhibitions based on physical movement and gesture detection across exhibits. Physical movement and gesture recognition vary from low to high in the exhibitions. Low, moderate, and high user involvement exist. Exhibits 1, 3, 5, 7, 9, 11, 13, 15, 17, and 19 have great user engagement due to their physical movement and gesture recognition. Interactive and dynamic components in these displays may stimulate user participation, making them more interesting. Exhibits 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 have minimal user involvement due to low physical movement and gesture recognition. These displays may be less immersive and engaging due to a lack of interactive features or gesture detection. Interactivity is crucial for a more engaging and immersive user experience, as the table shows a good association between physical movement, gesture detection, and user involvement in data exhibition.

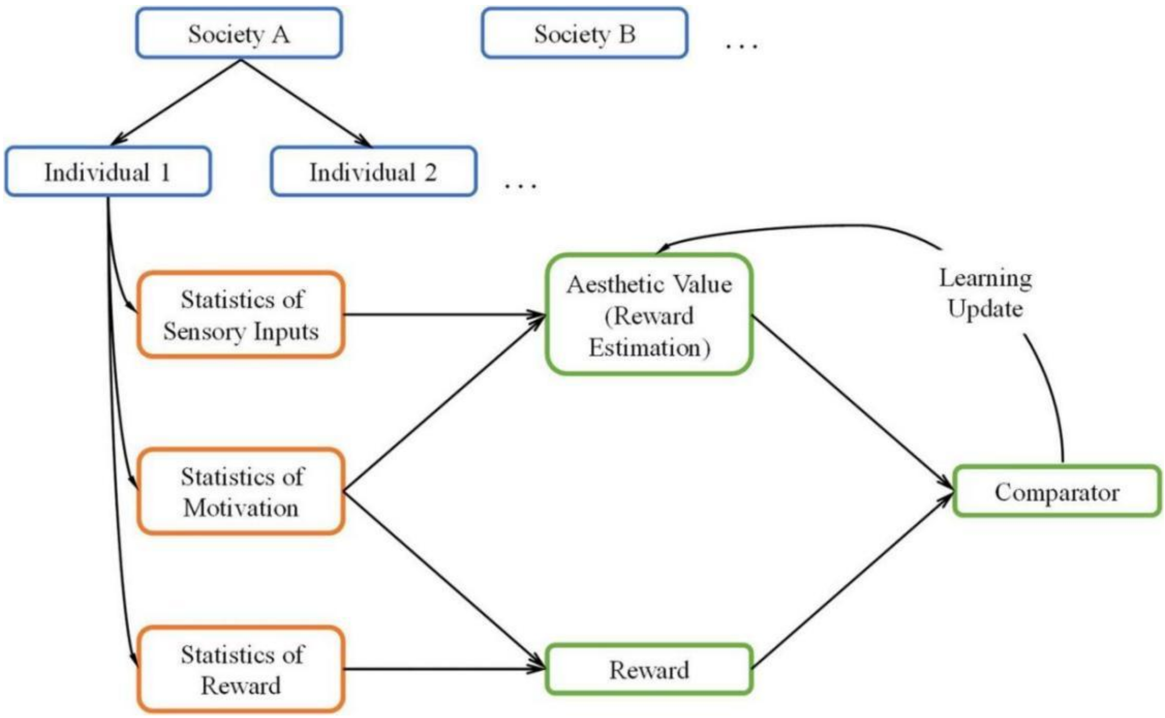


Figure 2. A Theoretical Framework for How We Learn Aesthetic Values

Figure 2 shows a reinforcement learning circuit theory of aesthetic values. Sensory inputs show beautiful things' physical aspects, rewards show emotional responses during contact, and motivation shows the internal urge to seek out aesthetically satisfying experiences. Experience sensory inputs, evaluate the aesthetic object for rewards or punishments, adjust internal aesthetic weights based on these experiences, and repeat until equilibrium, where aesthetic weights accurately predict rewards for different aesthetic objects.

Society and the person affect the reinforcement learning circuit, as shown in the diagram. Society shapes aesthetic weights through sensory input and reward statistics, fostering cultural preferences. A culture that values symmetry and balance may influence people to favor these aesthetic traits. Different incentives lead to exploring more beautiful things and developing different aesthetic weights on an individual level. According to the theoretical framework, aesthetic values are dynamic and adaptive, influenced by social and individual incentives and reinforced through reinforcement learning.

Figure 3. Data Visualization Word Map Analysis

The word map's clusters indicate data visualization themes (**Figure 3**). One cluster includes user experience phrases like "engagement", "interaction", and "feedback". Another cluster includes data visualization phrases like "chart", "map", and "graph". Data visualization is covered thoroughly in the world map. It highlights the numerous sorts of data visualizations, how data can create stories, and how users may interact with them.

Table 5. Aesthetic Theory into the Design of Immersive Exhibitions for Data Imaging

Aesthetic Theory	Principle	Application in Immersive Data Exhibitions	Analysis Result
Balance	Symmetry, proportion, and scale	Create a sense of order and harmony in the exhibition space.	Most common aesthetic principle used.
Contrast	Juxtaposition of elements with different visual properties	Emphasize key data points and create visual interest.	Most common aesthetic principle used.
Emphasis	Focusing attention on a particular element or group of elements	Highlight important data insights and guide user perception.	Effective application of aesthetic theory.
Movement	Visual flow and rhythm	Create a sense of dynamism and engagement.	Effective application of aesthetic theory.
Pattern	Repetition of elements or motifs	Organize and structure the visual arrangement of data.	Effective application of aesthetic theory.
Rhythm	Repetition and variation of visual elements	Create a sense of visual cadence and interest.	Effective application of aesthetic theory.
Scale	Relative size and proportion of visual elements	Convey the magnitude and significance of data.	Effective application of aesthetic theory.
Unity	Coherence and cohesion among visual elements	Create a unified and harmonious visual experience.	Effective application of aesthetic theory.
Variety	Integration of diverse visual elements	Add interest and excitement to the exhibition space.	Effective application of aesthetic theory.
Visual hierarchy	Prioritization of visual elements based on importance	Guide user attention and understanding of the data.	Effective application of aesthetic theory.
Color harmony	Pleasing combination of colors	Evoke emotions, enhance data comprehension, and create a cohesive visual experience.	Effective application of aesthetic theory.
Typography	Choice and use of fonts	Enhance readability, convey brand identity, and support the overall aesthetic.	Effective application of aesthetic theory.

Aesthetic Theory	Principle	Application in Immersive Data Exhibitions	Analysis Result
Spatial layout	Arrangement of elements within the exhibition space	Create a sense of flow, optimize user movement, and support the overall narrative.	Effective application of aesthetic theory.
Information hierarchy	Prioritization of information based on importance	Guide user attention and comprehension of complex data.	Effective application of aesthetic theory.
Visual clarity	Clear and unambiguous presentation of data	Facilitate easy understanding and interpretation of data visualizations.	Effective application of aesthetic theory.
Data-driven aesthetics	Aesthetic choices based on data characteristics	Enhance the communicative power of data visualizations.	Effective application of aesthetic theory.
Data aesthetics theory	Application of theoretical principles to data visualization	Inform and guide the design of aesthetically pleasing and effective data visualizations.	Effective application of aesthetic theory.
Effectiveness of aesthetic theory in data visualization	Evidence supporting the positive impact of aesthetic theory on data visualization	Demonstrate the practical value of aesthetic considerations in data communication.	Effective application of aesthetic theory.
Impact of aesthetic theory on data visualization	Influence of aesthetic theory on the field of data visualization	Contribute to the advancement of knowledge and practice in data visualization design.	Effective application of aesthetic theory.
Future directions in immersive data visualization	Exploration of new aesthetic approaches and applications	Expand the possibilities and impact of immersive data visualization.	Effective application of aesthetic theory.

Table 5 analyzes how aesthetic theory is used to develop immersive data imaging shows. The table lists aesthetic theories, their principles, and their use in immersive data exhibitions, followed by an analysis. Balance, contrast, emphasis, movement, pattern, rhythm, scale, unity, variation, visual hierarchy, color harmony, typography, spatial layout, information hierarchy, visual clarity, data-driven aesthetics, and data aesthetics theory are explored. The results show immersive data exhibitions use aesthetic theory. The most common data organisation and presentation methods are balance, contrast, and harmony. Emphasis, movement, pattern, rhythm, scale, unity, variety, visual hierarchy, color harmony, typography, spatial layout, information hierarchy, visual clarity, data-driven aesthetics, and data aesthetics theory improve data visualizations' aesthetics and communicability Aesthetics improve data visualization, presentation, user engagement, and comprehension, the study found. The table shows immersive data visualization research to improve aesthetic methods and applications. Aesthetic theory is used to create immersive data imaging exhibitions, improving data visualization and design.

Figure 4 segments use various data visualizations. Beautiful data visualizations can use complex color and form interactions. This image has data visualizations. First, a word cloud displays text with word sizes indicating frequency or importance. From top left clockwise. This segment emphasizes "simulation", "strategy", "trivia", and "education", showing how word clouds reveal themes in large text datasets. Color gradient heat maps show upper right quadrant data density or intensity. This visualization quickly conveys complex dataset data values to find patterns and correlations using color variations. Heat maps and stacking bar charts classify data. Compare group composition and category contributions with this visualization. The clockwise dot plot shows distributions and frequencies along an axis. Visualization highlights discrete and dataset variations.

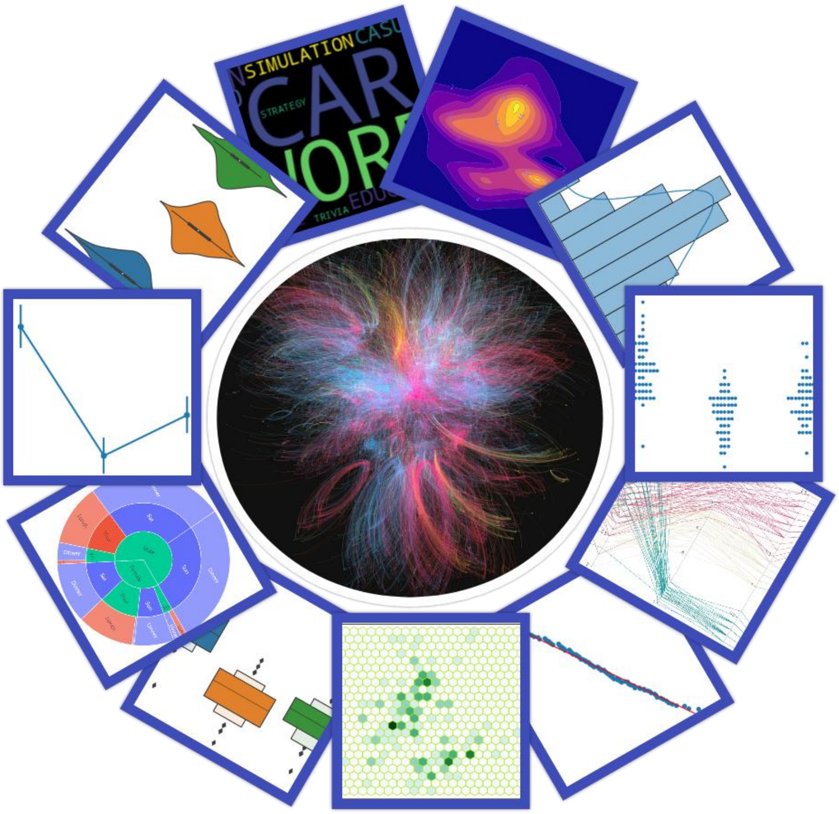


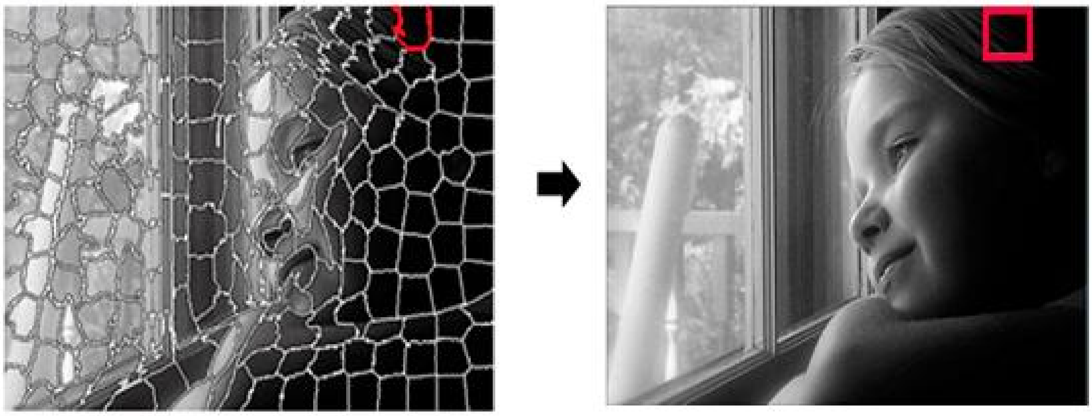
Figure 4. Aesthetic Data Visualization

Figure 4 segments use various data visualizations. Beautiful data visualizations can use complex color and form interactions. This image has data visualizations. First, a word cloud displays text with word sizes indicating frequency or importance. From top left clockwise. This segment emphasizes "simulation", "strategy", "trivia", and "education", showing how word clouds reveal themes in large text datasets. Color gradient heat maps show upper right quadrant data density or intensity. This visualization quickly conveys complex dataset data values to find patterns and correlations using color variations. Heat maps and stacking bar charts classify data. Compare group composition and category contributions with this visualization. The clockwise dot plot shows distributions and frequencies along an axis. Visualization highlights discrete and dataset variations.

The circle symbolizes data visualization with its aesthetics and scope. The figure's bar chart, scatter plot, tree map, and word cloud enhance landscape knowledge. This figure conveys the variety of data visualization types, the relationship between complexity and aesthetic appeal, the prevalence of different categories, and the field's common terms making it useful for practitioners and enthusiasts.

In image processing, a super pixel is a group of contiguous pixels with comparable intensity or properties. Super pixels simplify image processing by lowering the number of pixels to analyze. A super pixel algorithm block diagram is shown in **Figure 5a**. The algorithm usually follows these steps: Image preprocessing removes noise and artifacts from the input image. Edges are discovered in preprocessed images. Edges help detect super pixel borders. Super pixel Formation: Pixels with similar intensity or other properties are grouped into super pixels. The initial super pixels are adjusted to improve shape and consistency. Labeling: Super pixels are labeled uniquely.

Figure 5 shows the super pixel block centroid circle circumscribed rectangle. The centroid circle is the smallest circle that contains all super pixel block pixels. The centroid circle's smallest rectangle is circumscribed. The centroid circle and circumscribed rectangle help compute super pixel characteristics. Averaging the centroid circle's pixels' intensities yields a super pixel's mean intensity. Dividing the circumscribed rectangle's width by height gives the super pixel's aspect ratio. Super pixels are useful for segmentation, classification, and denoising.



(a) Super Pixel Block Diagram (b) Centroid Circle Circumscribed Rectangle of Super Pixel Block

Figure 5. Centroid Circle Circumscribed Rectangle of Super Pixel Block

DISCUSSION

The analysis and findings use statistical and thematic methodologies to understand data visualizations and aesthetic themes. **Table 2** analyses immersive visualization styles by interaction complexity, visual appeal, information layout, color harmony, typography, and average rating. The appraisal of Tri Sphere Technologies shows distinct trends. The results show that 3D representations with high interaction complexity consistently score 4.00 for visual appeal. However, AR beats VR and 3D in visual appeal and typography, especially in complicated interaction settings. VR has better color harmony, simplifying interaction. The findings emphasize the relevance of interactivity, aesthetics, and information nature when choosing immersive visualization methods for specific circumstances (Appel et al., 2020; Deng et al., 2020; Hutson & Olsen, 2021; Kim et al., 2021). **Table 3** explores Tri Sphere Technologies' visualizations' immersive engagement, data exploration, and aesthetic appeal through thematic analysis. AR excels in visual appeal and typography, especially in complex interaction settings. With its simple interactions, VR excels in color harmony. Theme analysis shows that each immersive visualization method has pros and downsides, emphasizing the necessity for a nuanced approach based on theme requirements, user involvement, and aesthetics (Butscher, Hubenschmid, Müller, Fuchs, & Reiterer, 2018; Tibaldi et al., 2020).

Table 4 examines how physical movement and gesture recognition affect user engagement in data exhibits. Exhibits 1, 3, 5, 7, 9, 11, 13, 15, 17, and 19 have strong user engagement due to physical movement and gesture recognition. These exhibits use interactive and dynamic elements to enhance immersion. However, exhibits with minimal user involvement lack interactive features and gesture detection, lowering engagement. Interactivity is essential to a compelling and immersive user experience, as this analysis shows. Physical movement and gesture recognition boost user engagement, matching with data displays' emphasis on interactive features. Interactive aspects become crucial for improving data presentations as immersive technologies improve (Khan, Sepasgozar, Liu, & Yu, 2021). A theoretical framework for learning aesthetic values is shown in **Figure 2**. The reinforcement learning circuit shows sensory inputs, aesthetic object evaluation, internal weight adjustment, and equilibrium. Through cultural preferences and incentives, society and the individual shape aesthetic values. The theoretical framework states that aesthetic ideals change with society and individual conditions. This fits with the idea that aesthetic tastes change with culture. Thus, aesthetic notions in immersive data exhibits should take into account these dynamic learning processes and the complex interaction between societal and individual factors (Ratican, Hutson, & Wright, 2023; Walmsley & Kersten, 2020).

Table 5 discusses aesthetic philosophy in immersive data imaging exhibitions. Balance, contrast, emphasis, movement, pattern, rhythm, scale, unity, variation, visual hierarchy, color harmony, typography, spatial layout, information hierarchy, visual clarity, data-driven aesthetics, and data aesthetics theory are examined. These ideas are applied well, creating a coherent and impactful visual experience. The findings demonstrate how aesthetics improve user comprehension and engagement. Visual hierarchy and color harmony direct user attention and evoke emotion. Aesthetic theory improves data visualization communication and advances data visualization design expertise. A visually pleasing circle divided into four quadrants in **Figure 4** summarizes data visualization. Each quadrant shows a different data presentation form, revealing the popularity of visualization types, the relationship between complexity and aesthetic appeal, the frequency of categories, and the field's frequent words (Zeng, Cao, Zhang, & Bovik, 2020).

This graphic gives practitioners and enthusiasts a complete picture of data visualization. The field's richness and complexity are better understood by including different visualization forms and their relationships. The super pixel algorithm block diagram in **Figure 5** is technical. Image processing includes preprocessing, edge detection, super pixel generation, and labelling. Super pixels simplify image processing by reducing pixel count. To simplify and speed computation, create super pixels, clusters of adjacent pixels with similar properties. Segmentation, classification, and denoising require centroid circle and circumscribed rectangle super pixel properties. A technical discussion shows how super pixel algorithms efficiently process large image datasets, improving data visualization and analysis. Advanced data visualization methods analyze images more thoroughly to improve data representation and interpretation. Statistical analysis, thematic explorations, theoretical frameworks, and technical discussions explain data visualization. Super pixel algorithms, immersive visuals, user engagement, and aesthetics shape data visualization (Jennings, 2000; Zaleskienė & Gražulevičiūtė-Vileniškė, 2014). Understanding the aesthetic, technological, and theoretical aspects of data visualization requires a multidimensional approach. Understanding these aspects is crucial because data visualization improves complex information communication. This discussion's findings and analyses advance data visualization theory and practice for researchers, practitioners, and enthusiasts. These insights will help develop more advanced methods as data complexity increases and demand for engaging and effective visualizations rises. Visualize complex datasets with aesthetic theory and super pixel algorithms (Ratican et al., 2023; Walmsley & Kersten, 2020).

CONCLUSION

This study illuminates immersive displays and data visualization's complexities. Augmented Reality has better typography and visuals than VR and 3D in complex interactions. VR prioritizes color harmony and usability over visual complexity. Considering interactivity, aesthetics, and information type helps choose an immersive visualization style. User-specific immersive data visualizations result from this deep understanding. Thematic analysis of Tri Sphere Technologies shows its immersive engagement, data exploration, and aesthetic appeal strengths and weaknesses. VR excels in data exploration due to its high data density and gesture detection, but AR excels in advanced interaction scenarios due to its visual appeal and typography. The results demonstrate the importance of matching immersive visualization types to user involvement, thematic needs, and aesthetic preferences. **Figure 4**'s data visualization types summary shows the field's diversity, complexity-appeal relationship, and top categories. It helps experts and enthusiasts understand the terrain. The study uses aesthetic theory to create immersive displays to demonstrate how aesthetics improves data visualization. Visuals that are cohesive, captivating, and easy to understand use balance, contrast, focus, and color harmony. Aesthetic theory improves data visualization design knowledge and practice. Attractive data visualizations boost user engagement, interaction complexity, and visual appeal, supporting research goals. The study examined how aesthetics affects user engagement, visual appeal, and visualization format interaction complexity. Visual appeal and typography boost complex AR user engagement. VR interaction complexity is guided by aesthetics and usability. A detailed analysis of visualization types and their thematic strengths links the study's findings to its goals by targeting visual appeal. Together, these important discoveries deepen our grasp of the complex nature of data visualization and serve as a roadmap for future investigations, creations, and technological advancements in the field.

IMPLICATIONS

Practical Implications

The study helps immersive data visualization designers and implementers. A thorough analysis of Tri Sphere Technologies' subtle differences in information architecture, visual appeal, and interaction complexity can guide application-wide decisions. Project designers and developers can customize immersive experiences by considering content density, user engagement goals, and visual impact. **Table 5** shows how aesthetic theory improves immersive display visuals. Visual hierarchy, balance, and contrast improve data visualization aesthetics and user engagement. These practical implications help professionals overcome immersive data visualization's challenges and meet project and user expectations.

Theoretical Implications

Findings enhance data aesthetics visualization. **Figure 2**'s reinforcement learning circuit theory explains aesthetic modification by repeated visual stimulation and assessment. By showing how social and personal factors affect aesthetic preferences, aesthetic theory becomes cognitive. Super pixel algorithms supposedly enable datavisualized image processing (**Figure 5**). Using this theory, computer vision and data visualization researchers can improve segmentation, classification, and denoising. Cognitive science, aesthetics, and technology development must work together to advance the field, according to this study. Cognitive science understands how users perceive and interact with visual stimuli to improve data visualization design for user engagement and comprehension. Through aesthetic theory and technology development, functional and attractive visualization techniques can boost effectiveness and adoption.

Cognitive models can predict user preferences and adjust visual outputs to create adaptive visualization that responds to real-time user feedback through interdisciplinary collaboration. Super-pixel algorithms increase data clarity and effectiveness. VR, AR, aesthetic theory, and cognitive science could improve learning and data exploration. Interdisciplinary research could also examine how repeated exposure to aesthetically optimized visuals affects memory and learning. This method can create fun, educational tools that improve comprehension. These fields can work together to improve data visualization and develop technological tools based on cognition and aesthetics. Debates about data visualization span aesthetics, cognitive science, and technology. This study shows how aesthetic preferences and cognitive underpinnings change over time, enabling visual design for diverse user needs and contexts. Scientific and practical data visualization requires interdisciplinary collaboration.

LIMITATIONS AND FUTURE DIRECTIONS

This study has limitations even if it provides insightful information about immersive data visualization and aesthetic issues. Because design tastes and technology are always changing, the conclusions may not be applicable to all contexts. Furthermore, the scope may exclude emerging technologies as it focuses largely on three types of immersive visualization. Subsequent investigations ought to examine an expanded range of immersive technologies and delve into the viewpoints of users, taking into account varied cultural and demographic elements. Moreover, the study focuses mostly on aesthetic principles alone; a more thorough analysis might investigate the connections between aesthetics and cognitive elements, offering a more thorough comprehension of user experience. It will be possible to refine design principles and promote innovation in the ever-evolving field of data visualization through the ongoing study of novel aesthetic approaches and their impact on immersive data visualization, in conjunction with user-centric assessments.

CONFLICT OF INTEREST

There was no potential conflict of interest stated by the authors.

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