

Case Study

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Cross-Dimensional Representation of Space and Memory: A Multi-Sensory Communication Study of Science and Technology Museums through the Perspective of Artistic Narrative

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KEY WORDS

Artistic Narrative; Science and Technology Museum; Multi-Sensory Communication; Spatial Representation; Cultural Memory

ABSTRACT

In an era where digital technology profoundly reshapes cultural experiences, science and technology museums are undergoing a pivotal transition from static, knowledge-authoritative exhibition halls to dynamic, public-participatory experiential venues. This study focuses on the core perspective of artistic narrative, aiming to systematically explore how science and technology museums achieve paradigm innovation in scientific communication through cross-dimensional sensory representation. The article indicates that effective communication of scientific knowledge has evolved from purely visual presentation into a multi-sensory collaborative design practice unified under artistic narrative thinking. Through deep analysis of cutting-edge science museum cases globally, this study reveals how the perceptual structure 'visual narrative-auditory landscape-olfactory awakening-tactile interaction' is artistically rendered. This approach integrates abstract scientific principles with grand technological narratives, forging immersive, empathetic, and embodied physical experiences and collective memories for the public. Cross-dimensional representation grounded in artistic narrative not only reshapes the physical and psychological space of museums as 'sites of memory,' but also establishes a new communicative paradigm linking cognition, emotion, and values, provides theoretical pathways and practical strategies for the innovative development of future science and technology museums.

INTRODUCTION

Research Background

As custodians of collective historical memory and presenters of knowledge systems, museums are undergoing a profound revolution in their functional para-

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digms. Globally, science and technology museums centered on technological exploration and scientific literacy are no longer content to serve merely as venues for displaying sophisticated instruments and intricate models. Driven by the dual forces of the experience economy and digital storytelling, public expectations have shifted from 'observing knowledge' to 'experiencing knowledge', and from 'comprehending conclusions' to 'engaging with processes'. This transformation poses a core challenge for science and technology museums: how to transcend traditional linear communication models reliant on text, images, and artefacts, rendering invisible force fields, microscopic structures, vast datasets, and grand historical narratives perceptible, comprehensible, and resonant?

Against this background, constructing multisensory experiences emerges as the key solution. Yet, the mere accumulation of sensory elements does not inherently lead to effective cognition or profound emotional resonance. The dazzling display of technology may degenerate into hollow spectacle, failing to touch the essence of scientific communication. Therefore, this study advocates introducing 'artistic narrative' as a core unifying perspective and analytical framework. Artistic narrative denotes not mere aesthetic embellishment, but a systematic methodology for creative translation and narrative construction. It entails employing design languages—such as spatial arrangement, light and shadow, sound, materials, and interactive rhythms—to envelop science's rational core within sensory experiential forms, thereby bridging the gap between technology and humanity, objectivity and subjectivity, cognition and emotion. This study seeks to address the following question: Under the guidance of artistic narrative thinking, how can science and technology museums employ cross-dimensional sensory strategies to achieve more efficient, human-centered, and creative communication of scientific knowledge?

Literature Review and Research Synthesis

Core Theoretical Foundations

Spatial production Theory: Henri Lefebvre's (Henri Lefebvre, 1991) tripartite spatial theory—spatial practices, spatial representations, and represented spaces—provides the foundational framework for this study. Museum spaces are far from neutral containments; rather, they are social artefacts "produced" by power, knowledge, and ideology. Multisensory design, as a form of spatial practice, actively shapes visitors' behaviors and perceptions, transforming the museum into a lived and felt 'text.'

Cultural Memory Theory: Jan Assmann's (Jan Assmann, 2011) theory of cultural memory posits museums

as institutionalized, materialized 'lieux de mémoire' (memory sites), whose core function lies in stabilizing and transmitting collective identity. The storage and retrieval of memory rely not only on text but crucially on imagery, ritual, and embodied practices. Multi-sensory experiences represent a contemporary core pathway for the 'embodiment' of abstract memory.

Multisensory Design and Embodied Cognition Theory: Maurice Merleau-Ponty's (Maurice Merleau-Ponty, 1962) phenomenology and subsequent embodied cognition theory posit that cognition is deeply rooted in the interaction between the body and its environment. Sensory experience is not a mere appendage to thought, but the very form of thought itself. This provides a robust philosophical and psychological foundation for museums to foster deep understanding through the design of non-visual experiences such as touch and smell.

Current Research Approaches and Limitations

Current research primarily follows two approaches: firstly, the technological application approach, which focuses on how new technologies such as big data visualization create immersive experiences; secondly, the single-sensory approach, which explores the educational efficacy of specific senses like tactile or auditory perception. However, existing research exhibits the following limitations:

First, a lack of systematic coherence. Most studies either prioritize technological tools or discuss individual senses in isolation, lacking a high-level framework that organically integrates multisensory spatial narratives with the ultimate objectives of communication. In other words, technology often remains disconnected from experiential goals.

Second, weak design dimensions. 'Design' in relevant literature is frequently narrowed to visual or interface design, while the strategic value and cultural translation function of 'artistic narrative' thinking—as a holistic framework for storytelling and experience architecture—remains underappreciated and under-theorized.

Thirdly, insufficient attention is paid to the perspective of memory and long-term efficacy. Existing research predominantly focuses on immediate learning outcomes or engagement metrics, with scant consideration given to examining the profound cultural efficacy of multi-sensory communication from the angles of long-term cultural memory construction, identity formation, and social recognition.

Consequently, this study seeks to integrate the above theories, explicitly proposing an artistic narrative as the unifying framework. Centered on the cross-dimensional representation of space and memory as its core mechanism, it systematically analyses the underly-

ing logic and cultural value of multi-sensory communication in science and technology museums, thereby addressing gaps in current research.

CHARACTERISTICS OF MULTI-SENSORY COMMUNICATION RESEARCH IN SCIENCE AND TECHNOLOGY MUSEUMS FROM AN ART NARRATIVE PERSPECTIVE

Art Narrative: From Aesthetic Adornment to Narrative Framework

Within science and technology museums, art narrative serves as the pivotal translation system enabling scientific knowledge to be perceived rather than merely told. It constitutes a structural mindset that permeates the entire process from conceptualization to experiential engagement. The core content of science museums is objective, logical, and even abstract. Artistic narrative, by contrast, is inherently subjective, sensory, and concrete. Their convergence lies in a shared pursuit of experience construction: transforming data into visual landscapes, principles into interactive rituals, history into immersive dramas, and concepts into bodily memories. For instance, a theory of the Big Bang may be expressed through the coordinated interplay of gradually shifting light and shadow, low-frequency sound vibrations, progressively rising ambient temperatures, and floor vibrations simulating expansion beneath one's feet. Such expression is not a diagrammatic illustration of the theory, but rather an artistic translation and emotional interpretation of its awe-inspiring grandeur and irreversibility.

In this study, artistic narrative is defined as a strategic process of translation and integration. It aims to transform the rational core of science and the material form of technology into a phenomenological experience capable of eliciting emotional resonance and fostering meaning generation through multi-layered perception. It concerns the interplay of space, rhythm, light and shadow, emotion, sound, and landscape—an interactive ritual and material poetics that serves as a creative bridge connecting the objective world (the technology) with subjective experience (the public). Within the context of science and technology museums, artistic narrative serves as the key to enabling knowledge to achieve a 'soft landing' and fostering resonance with technology.

Communication Principles: Spatial Memory and Cross-Dimensional Narrative

Space: Refers to the physical museum space extended by media technology into a mixed-reality environment, and most crucially, the psychological and

emotional space generated by the experience. It serves as both the 'theatre' where communication unfolds and the 'canvas' upon which narratives are inscribed.

Memory: Refers to the cognitive patterns and emotional affiliations formed at individual and societal levels through museum experiences, concerning technology, knowledge, historical processes, human intellect, and cultural values. It constitutes the desired effect of communication and the 'imprint' that artistic narratives seek to engrave.

Cross-dimensional inscription: This refers to the use of multi-sensory forms of expression (visual, auditory, tactile, olfactory, etc.) to create an interwoven, three-dimensional record of meaning across spatial dimensions. It transcends the limitations of singular sensory pathways or linear narratives. Through the symphony and dialogue of senses, it simultaneously weaves knowledge networks within the visitor's body and mind, evoking emotional resonance and fostering value recognition. Thus, it achieves the transcendence from mere information transmission to the 'forging of memory'.

Core Concept: the Spatial-Sensory-Memory Communication Structure

The core concept emphasized in this study is the spatial-sensory-memory communication structure. It focuses on the following central questions: How can artistic narrative thinking consciously and strategically organize diverse sensory materials (including digital technologies) to shape the visitor's attentional flow, emotional trajectory, and cognitive pathways? How does it transform science museums into meaningful 'perceptual theatres' capable of deep dialogue with visitors?

This communication structure emphasizes procedural wholeness (rather than simple addition), interactivity (where audiences are co-authors), and generativity (where memory emerges as an outcome). Subsequent chapters analyzing visual, auditory, tactile, and olfactory elements within museums globally will be situated within this integrated perspective, exploring how these sensory components collectively co-author scientific narratives as artistic perceptual elements.

VISUAL NARRATIVE: CONSTRUCTING SYMBOLIC SPACES AND COGNITIVE INTERFACES

As a primary sensory channel for human information acquisition, vision occupies a central position in museum exhibitions. It serves not only as the immediate means of presenting artefacts, but also as a vital medi-

um for conveying cultural values and scientific concepts.

Architecture and Space: the Primary Framework of Narrative and Prologue To Experience

Architecture serves as the prologue to experience, embodying the grandest artistic narrative space itself. For instance, the Deutsches Museum's main building occupies an island on Munich's River Isar. Its very location shapes the 'museum' into an 'island of knowledge' isolated from everyday urban life, symbolizing that scientific exploration constitutes a distinct and dedicated domain. Its vast central atrium and tiered exhibition galleries metaphorically embody the immensity of humanity's technological knowledge through spatial grandeur.

By contrast, the National Museum of Emerging Science and Innovation (Miraikan) in Tokyo's Odaiba district, situated at the forefront of Tokyo Bay, establishes its narrative focus on 'future technology' from the very first impression through its modern, futuristic architectural style. Architectural space design represents the highest level of immersive artistic conception. The contrast between these two approaches vividly demonstrates how spatial design functions as a 'meta-narrative,' shaping visitors' initial perceptions and emotional expectations of technology in fundamentally different ways. The layout, circulation scale, and lighting environment collectively establish the emotional tone and cognitive framework of the narrative.

Visuals and Installations: the Art of Translation From Interpretation

For abstract concepts, the core challenge and supreme value of visual design lies in 'translation'. Within science communication, the visual translation of abstract content serves as the pivotal bridge connecting public understanding with specialist knowledge.

The iconic exhibit 'Geo-Cosmos' at the National Museum of Emerging Science and Innovation (Miraikan) in Japan offers a classic example. Designed by Mitsubishi Electric, this installation features a 6-metre diameter spherical display. Its surface is covered with 10,362 OLED display modules, boasting a resolution of tens of millions of pixels. Suspended 18 meters above the ground, it presents real-time global weather cloud maps, ocean temperature data, and acidification information. Its artistic merit lies in two aspects: Firstly, the choice of the most symbolic form-the sphere-directly evokes the core imagery of 'humanity's shared home'; Secondly, its visual design transforms vast data streams through algorithmic filtering and aesthetic coloring into a serene, profoundly flowing visual language

of 'planetary respiration.' Visitors are first captivated by its stunning aesthetic impact, evoking emotional affinity and reverence, which then sparks curiosity about Earth's environmental sciences-perfectly achieving an elevation from artistic immersion to scientific understanding.

The 'Light of Wisdom' exhibition zone at Shanghai Science and Technology Museum showcases the theatrical artistic reconstruction of classic physics experiments. This exhibit employs the principle of polarized light filtering. An optical system comprises two sets of polarizing filters with perpendicular transmission axes (90° angle between transmission axes) and transparent acrylic tubes. When visitors observe through polarizing filters at specific angles, the inner walls of the tubes appear as a 'visual black wall,' simulating physical obstruction. It intuitively demonstrates polarized light's selective filtering of electromagnetic wave vibration directions. This design transforms the abstract concept into an interactive visual obstacle game. As visitors navigate the 'maze,' they spontaneously grasp the fundamental nature of light polarization. Beyond demonstrating the principle, it elevates the scientific phenomenon itself into a visually striking.

Interface and Information Design: Guiding Exploration Through Logical Visualization

Within interactive exhibits, the visual interface serves as a "map" guiding cognitive processes. Effective interface design simplifies complex operations or comprehension through clear visual hierarchies, logical iconography, and immediate status feedback, transforming them into intuitive exploration experiences. For instance, in interactive installations at science museums explaining complex systems-such as urban transport networks or the human immune system-visual techniques like particle-based dynamic flowchart simulations or layered infographics are commonly employed. These allow visitors to intuitively observe the interconnections and dynamic shifts among system elements through simple actions like swiping selections, thereby grasping their operational mechanisms. Such design constitutes an artistic narrative practice that visualizes abstract logic.

AUDITORY NARRATIVE: SHAPING EMOTIONAL SOUNDSCAPES AND NARRATIVE RHYTHM

Sound possesses a unique capacity for storytelling and emotional resonance, transcending visual limitations to create immersive visitor experiences. Within museums, the skillful integration of auditory elements

can evoke visitors' emotional memories, enhancing their comprehension of and connection to scientific knowledge.

Environmental Soundscapes: Spatial Orientation and Emotional Rendering

Sound stands as one of the most potent tools for establishing spatial authenticity and emotional tone. Within exhibition spaces simulating specific scientific environments or technological scenarios, meticulously designed three-dimensional surround soundscapes prove indispensable. For instance, in an exhibition zone simulating deep-sea exploration, a persistent low-frequency hum (emulating deep-sea pressure), intermittent hissing from hydrothermal vents, and artistically processed whale calls instantly transport visitors from the bustling gallery environment into the profound, mysterious, and unknown depths of the ocean. This sound design serves not as background accompaniment but as the foundational element defining the space. It directly influences the subconscious, eliciting corresponding emotional responses such as awe, curiosity, or tranquillity. Theoretical research indicates that multisensory cues—particularly auditory ones—significantly enhance the realism of virtual or simulated environments and the user's sense of presence.

Interactive Feedback Sound Effects: Imbuing Operations With Textural Quality and Meaning

When audiences interact with exhibits, sound provides immediate, expressive sensory feedback—a design requiring exceptional artistic precision. For instance, pressing the start button on a century-old generator model should be accompanied by the heavy, gradually accelerating clatter of machinery coming to life, followed by the hum of electrical current; completing a virtual gene-splicing sequence should trigger a crisp, melodic synthetic tone symbolizing the order of life. These sound effects are not arbitrarily added but serve as designed 'auditory signatures.' They transform cold, mechanical operations into events with tactile quality, causal significance, and even ritualistic resonance, greatly enhancing the satisfaction of interaction and the understanding of cause and effect.

The VR immersive experience of the 'Complete Map of the World' at Nanjing Museum employs such design principles. When visitors touch virtual artefacts, they may hear the chime of bronze or stone or the rustle of ancient scrolls turning. This approach ritualizes simple actions, imbuing interactions with tactile and emotional weight. It fosters a sense of dialogue with history rather than mere machine operation.

Narrative Audio: From Mono Commentary to Stereo Dialogue

The design ethos of audio guide systems is undergoing a profound shift from 'broadcast' to 'dialogue', with cutting-edge practices focused on developing intelligent audio systems capable of scene-aware and personalized storytelling. Envisioned upon current trends in AI and context-aware technologies, in future science centers' 'Space Exploration' galleries, when visitors pause before the Core Module model, the headset narration could seamlessly transition from standard module descriptions to authentic audio recordings of astronauts working inside the module during its operational years. Alternatively, it might initiate an open discussion about the psychological challenges of prolonged space habitation. This design renders audio narration both intelligent and considerate, dynamically adjusting narrative content and depth according to visitor behavior and points of interest. It thus becomes a conversational companion guiding exploration, rather than a commentator.

TACTILE AND OLFACTORY NARRATIVE: ACTIVATING EMBODIED MEMORY AND EMOTIONAL REFERENCING

Touch constitutes humanity's most direct mode of interaction with the external world, enabling concrete cognition of objects through bodily contact and perception. As a profoundly personalized and culturally embedded sensory experience, smell possesses the capacity to directly evoke deep-seated memories and emotional responses. Within museum contexts, the interplay of tactile and olfactory sensations not only heightens audience engagement but also furnishes embodied pathways for the internalization of scientific knowledge.

Tactile Interaction: Knowledge Within Embodied Memory

The essence of tactile design lies in creating 'meaningful physical contact', forging direct pathways to bodily memory and subconscious emotions.

The Deutsches Museum possesses an extensive collection of operable original machinery and intricate models, constituting one of its most distinctive educational approaches. Visitors may manually rotate a colossal flywheel requiring multiple individuals to turn it, experiencing inertia's immense force; or manipulate gear sets with varying ratios to intuitively grasp the conversion between torque and rotational speed. Such experiences transform abstract physical principles into tangible muscular sensations and perceptible resis-

tance in the hands, forging exceptionally robust embodied memories.

Shanghai Science and Technology Museum's Relativity Theatre, while incorporating dramatic elements, represents a bold attempt to render an extremely abstract theory tactile through motion-simulated seats that mimic gravitational forces. Its aim is to enable visitors to feel the theory with their entire bodies. Future science museums could also integrate physical interaction with digital enrichment. For instance, when visitors turn a real crank handle, a large screen before them could synchronously display enlarged views of the internal gear mechanisms and dynamic data changes, thereby complementing and enhancing tactile and visual cognition.

Olfactory Design: Scent Tracing and Emotional Awakening

In science museums, the application of scent presents both greater challenges and greater potential. Its value lies in constructing a sense of authenticity and emotional resonance that cannot be replicated by other senses.

In ecological exhibits, simulating tropical rainforest environments with scientifically reconstructed composite scents (moist earth, floral notes of specific plants) provides a faster entry pass than any visual backdrop, instantly establishing powerful scene authenticity and emotional connection.

Within material science or historical chemistry exhibits, allowing visitors to distinguish between new and aged rubberwood, pine, teak, or historical printing inks via controlled-release scent devices under strict safety protocols, amounts to conducting an 'archaeology of odors' - an implicit technological history read through the nose.

The artistry of olfactory design in science venues lies in the meticulous selection of scents, precise concentration control, and their seamless integration with narrative touchpoints, transforming them into uniquely evocative "anchor points" in memory. Such designs must adhere to ethical principles of non-compulsory, optional, and prompted engagement, while fully accounting for allergies and individual preferences.

CONCLUSION: TOWARDS A COLLABORATIVE 'SYMPHONY OF PERCEPTION'

Through systematic research of cross-cultural practices in science communication within multi-sensory museums, this section comprehensively summarizes the findings. From revealing the mechanisms of synergistic

interaction across four perceptual dimensions to distilling practical strategies and outlining future research directions, it aims to provide theoretical and practical guidance for cross-cultural design in museum science communication.

Research Findings and Main Conclusions

Under the perspective of artistic narrative, perceptual communication in science and technology museums is by no means a mechanical summation of sensory channels, but rather a meticulously orchestrated 'sensory symphony'. Through theoretical construction and case analysis, this study confirms the pivotal value of employing artistic narrative to unify multi-sensory communication in the transformation of science museums. The core conclusions are as follows:

First, artistic narrative constitutes the overarching principle for successful cross-dimensional communication. It transcends mere technological integration or sensory stimulation, serving as a strategic narrative framework designed to create profoundly meaningful experiences. It determines both the 'why' (narrative purpose) and the 'how' (presentation method) of organizing sensory elements, ensuring all experiences converge towards a unified communicative objective.

Second, the essence of multi-sensory communication lies in the representation of museum spaces and public memory. The visual constructs the narrative stage and its appearance; the auditory lays the emotional melody and rhythm; the tactile provides embodied knowledge memory; while the olfactory connects the intimate depths of memory with the authenticity of emotion. Together, they transform the museum from a static physical container into a vibrant field capable of producing collective technological and cultural memory.

Thirdly, effective communication should adhere to the principle of perceptual synergy rather than mere simple addition. Sensory dimensions do not operate in isolation but resonate and progress in unison under the unified orchestration of artistic narrative, forming a cohesive force. For instance, the grandeur of visual spectacle requires the emotional resonance of sound, while the visceral impact of tactile experience demands visual causality to explain. Together, they weave a dense tapestry of experience, ultimately fostering complete cognitive schemata and enduring emotional resonance within the visitor's mind and body.

Theoretical Contributions and Practical Implications

Theoretical Contributions

This study proposes the core perspective of 'cross-dimensional representation of space and memory',

constructing an analytical model of 'multisensory collaboration under artistic narrative integration'. This model elevates museum multi-sensory research from instrumental and effect-oriented approaches to the cultural practice level of narrative construction and meaning generation, effectively bridging science communication with artistic storytelling, and spatial theory with design research.

Practical Implications

Regarding curatorial model innovation, future science museum curatorial teams should evolve from traditional 'content expert committees' into 'experience creation groups', incorporating interaction designers, sound artists, architects, cognitive scientists, and even theatrical narrative consultants to enable interdisciplinary collaboration from the outset of curation.

Regarding narrative process design, the starting point should shift from exhibit catalogues to 'visitor experience journey maps'. This involves reverse-engineering the cognitive objectives, emotional peaks, and sensory stimuli visitors should attain within each narrative unit, thereby meticulously designing the timing, intensity, and interactive logic of sensory interventions at key nodes.

Regarding assessment system renewal, we must transcend simplistic satisfaction surveys by adopting multimodal evaluation methods. These combine physiological sensing (eye-tracking, electrodermal response, EEG, etc.) with in-depth interview behavioral observation. This enables scientific assessment of artistic narrative efficacy across multiple dimensions: attention allocation, emotional fluctuations, cognitive load, and long-term memory retention.

Research Limitations and Future Prospects

Research Limitations

This study primarily employs in-depth qualitative analysis of representative case studies. Whilst striving for typicality, it has yet to undertake large-scale quantitative empirical research to precisely measure the contribution weights of different sensory dimensions across varying contexts and their interrelationships. Furthermore, the cases predominantly focus on resource-rich, large-scale national venues, with attention to smaller-scale community-based or specialized science centers requiring greater emphasis.

Future Prospects

Neuroaesthetics and Precision Design: With the increasing availability of neuroscience tools (such as portable fNIRS and EEG), future research may more precisely reveal causal relationships between specific colors, sound frequencies, material textures, and brain

regions associated with cognitive and emotional responses (e.g., the amygdala and prefrontal cortex). This would provide empirical foundations for multi-sensory design, enabling a shift from experience-driven to data-driven precision representation.

Distributed Memory Representation in the Metaverse: Within the metaverse context, museums' perceptual representation will entirely transcend physical boundaries. Designing shareable, collaborative virtual tactile and olfactory experiences for geographically dispersed, asynchronous audiences-while fostering new digitally native technological memory communities-presents an urgent frontier for exploration.

Inclusive Narratives and Ethical Frameworks: Future multi-sensory artistic narratives must deeply consider the diversity of perceptual capabilities. Designing equivalent and dignified multisensory alternatives or augmentations for visually impaired, hearing-impaired, and autism spectrum individuals constitutes a fundamental requirement of inclusive narratives. Concurrently, the ethical boundaries surrounding highly immersive sensory experiences-such as emotional manipulation, information overload, and privacy data collection-necessitate the establishment of reflective and regulatory frameworks through collaborative societal engagement.

In summary, the future competitiveness and cultural influence of science and technology museums hinge upon their ability to successfully evolve from mere venues for displaying knowledge into experiential settings that actively cultivate scientific culture and shape collective memory. Through artistic storytelling, they must achieve cross-dimensional perceptual expression. This grand narrative, composed with multisensory impressions, ultimately inscribes not only the scientific tales of past and present, but also the latent narratives of how we collectively perceive the world, understand ourselves, and envision the future.

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