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Research on Sound Visualization Design of Daily Life Carbon Emission Behavior from the Perspective of Ecological Integration

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Abstract: Against the backdrop of the intertwined goals of "dual carbon" and the concept of ecological integration, this study explores the application value of sound visualization technology in carbon emission behavior research. By extracting the acoustic characteristics of daily carbon emission behaviors and combining them with visual representation techniques such as thermal imaging, a translation path of "behavior-data-sound-visual" is constructed to form a multimodal narrative system. The study employs a combination of literature analysis, case integration, and technical experiments to develop sound visualization videos and graphic design works for nine typical carbon emission behaviors. Practice shows that this design method can effectively enhance public awareness of carbon emissions and environmental protection, providing new ideas and pathways for the innovative application of visual communication design in the field of environmental communication.

Key words: Visual audio; Dual carbon goals; Carbon emission behaviors; Visual communication; Information design

1 Introduction

Global climate change, as one of the most urgent and profound influencing factors of our time, directly affects the survival and well-being of people worldwide and is related to the future development of humanity. China's "dual carbon" strategic goal, proposed in 2020, namely achieving peak carbon emissions as soon as possible followed by carbon neutrality, represents the international responsibility China should bear as a major country and embodies the pursuit of a sustainable development path. It not only provides a strong action guide for global climate change response but also points a clear and firm direction for the socio-economic system's development towards a greener and low-carbon future. Currently, public awareness of carbon footprints in their own living spheres is still inadequate, which directly leads to weak initiative in participating in low-carbon actions and fails to form a sustained driving force. Although information visualization technology has been applied in environmental communication, its handling of carbon emission issues has not achieved ideal results. This phenomenon is mainly due to the singular

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form, lack of artistic appeal, and public difficulty in understanding complexity presented by current technologies. Therefore, this paper proposes a new integrated path combining behavioral datafication, sound visualization, and visual enhancement. Through mining behavioral data, integrating sound visualization algorithms, and applying thermal imaging sensing technology, it aims to realize an immersive interactive platform. Using nine typical high-energy consumption life scenarios such as cooking and driving, as experimental entry points, the platform hopes to break the framework limitations of traditional environmental education and build a new educational paradigm system combining cognitive guidance and practical support, thereby effectively stimulating public environmental awareness and action.

This research intends to utilize sound visualization technology to transform invisible and intangible carbon emission data into intuitive audiovisual expressions, thereby enhancing the public's awareness level of their own carbon footprints. Its core objectives are: to deeply analyze the sound characteristics of carbon emission behaviors; to create sound and visual design methods that meet communication requirements; to produce audiovisual works that can attract social attention; and to evaluate the value and practical effects of these works in environmental protection applications. Theoretically, it combines the principles of audio-visual synesthesia and data visualization concepts, opening up new pathways for information transmission. Practically, it provides practical case references for the communication of environmental topics from an interdisciplinary perspective and promotes the emergence of new models for public participation in the green transition.

In domestic research, sound visualization is mainly discussed within the realms of art, design and multimedia technology. Yu Hanyang, in the article "Implementation Paths and Application Strategies of Sound Visualization in Digital Display," provides a detailed analysis of the relevant theoretical framework(Yu H Y, 2022). Foreign scholars began researching this technology as early as the 1980s, achieving significant results in technological innovation and disciplinary system creation. Zhang Yinan, in the work "Sound Visualization Practice Based on Touch Designer Platform – Taking 'Rain-ball' as an Example," points out that as a highly integrated visual programming environment, Touch Designer, with its node-driven architecture, greatly simplifies the process of audio-visual interactive development and enhances the efficiency of creative expression(ZhangY N, 2023).Currently, this technology has gradually penetrated professional fields such as medical image analysis, military reconnaissance, and criminal investigation. Although some achievements have been made in artistic expression and technological implementation in academia, research on practical applications integrated with environmental behavior remains scarce, providing an important innovative entry point and development space for this study.

The innovation of this study primarily manifests in two aspects. From a thematic perspective, it integrates environmental issues with multimodal communication, constructing an immersive carbon emission narrative framework composed of visual symbols, auditory elements, and image information, offering a novel angle for the public to understand the climate crisis. Methodologically, it transcends traditional disciplinary boundaries by synthesizing interdisciplinary knowledge systems—visual culture, design theory, communication studies, and environmental science—to establish a systematic research paradigm. Through a combination of literature review, case analysis, and technical practice, it achieves seamless integration of the "data-sound-image" transformation process. Utilizing the Touch Designer platform for visualization and effect evaluation, the study ensures both academic rigor and practical applicability.

2 Interpretation and Impact Analysis of the "Dual Carbon" Target

2.1 Overview of Ecological Integration Concept and "Dual Carbon" Policy

Against the increasingly severe backdrop of global warming, China, as one of the world's largest carbon emitters, proposed the "dual carbon" goal in 2020: achieving peak carbon emissions by 2030 and carbon neutrality by 2060. This decision reflects China's commitment to fulfilling its international responsibilities under the Paris control targets and is also an inherent requirement for promoting China's energy structure transformation and upgrading to achieve high-quality development. The report of the 19th National Congress of the Communist Party of China incorporated the "dual carbon" goals into the overall layout of ecological civilization construction, with the concept of ecological integration becoming a crucial guiding principle for coordinating socio-economic development and natural system harmony.

The "dual carbon" policy profoundly impacts China's socio-economic development. Economically, the industrial structure transitions towards green and low-carbon, creating new growth points such as renewable energy and new energy vehicles. It strengthens corporate technological innovation capabilities and market competitiveness, while carbon market mechanisms also promote optimal resource allocation. Socially, public environmental awareness is enhanced, green lifestyles gradually become popular, and ecological environmental quality continuously improves, increasing people's quality of life and sense of happiness. The substitution of new energy for traditional energy enhances national energy security and reduces external dependence. The coordinated development of the energy system and ecosystem is also advanced. The "dual carbon" policy not only provides institutional guarantees for China's sustainable development but also strengthens its competitive position in the global green economic landscape, laying a solid foundation for the deep integration of high-quality development and ecological civilization construction.

2.2 International Perspective: Comparison of "Dual Carbon" Strategies

In the global context of addressing climate change, various countries have formulated different carbon reduction strategies based on their own circumstances, providing valuable experience for China's "dual carbon" goals. From an international perspective, the European Union employs an Emissions Trading System to control total carbon emissions in sectors such as energy, industry, and aviation through quota allocation. The United States relies on a policy mix including carbon taxes, renewable energy standards, and energy efficiency standards, while also engaging in international cooperation at the state level. China has established a national carbon emission trading market focused on electricity, steel, cement, and other sectors, and utilizes financial subsidies, tax incentives, and other forms to encourage enterprises to adopt low-carbon technologies and accelerate renewable energy development(Yang D D, 2025)

These research findings hold significant practical implications for China. Experience from EU carbon market reforms can be drawn upon to improve the design and operational efficiency of the domestic trading system. Reference can be made to the diversified policy tool combinations of the United States to construct a multi-level synergistic emission reduction mechanism during the localization process. Investment in R&D for low-carbon technologies such as clean energy and Carbon Capture, Utilization, and Storage (CCUS) should be increased to explore innovative solutions and accelerate the commercialization process of technologies. Active participation in global climate governance activities, especially under the guidance of the "Belt and Road" initiative, should deepen exchanges and cooperation

with European and American countries in areas like technological collaboration and joint research projects, jointly promoting green and sustainable development (Zhou, 2021).

2.3 Impact of "Dual Carbon" Policy on Public Life

The advancement of the "dual carbon" strategy has enhanced public environmental awareness. When making consumption decisions, consumers increasingly value the environmental attributes of products, preferring green commodities such as Grade-1 energy efficiency products, high-efficiency appliances, and organic food, gradually reducing purchases of high-carbon emission products. Second-hand trading and sharing economy models are accelerating their integration into people's daily lives, forming a trend towards new social lifestyles. From a policy support perspective, the government encourages enterprises to increase the supply of green products through financial subsidies, tax incentives, and other means, promoting the prosperity and development of markets for low-carbon building materials, eco-friendly home furnishings, energy-saving appliances, and other sectors, jointly committed to building a comprehensive and sustainable green consumption system.

With the implementation of the "dual carbon" policy, low-carbon travel has become a lifestyle accepted by the public, with green travel modes such as public transportation, walking, and cycling becoming increasingly popular. Taking Chongqing's Carbon Inclusion policy as an example, the policy enhances residents' willingness for green travel through incentives, demonstrating the synergy between policy guidance and individual behavioral norms in transportation carbon reduction.

The enhancement of public energy-saving and emission-reduction awareness is mainly manifested through specific daily behaviors, such as adjusting indoor temperature and humidity, adopting high-efficiency lighting, and installing water-saving fixtures. These seemingly minor yet widely applicable operational methods reduce household carbon emissions while providing crucial social support for achieving the "dual carbon" goals. Furthermore, in summary, residents are gradually forming green and low-carbon living habits in areas such as diet, housing, and travel. Measures like adjusting food composition and choosing energy-efficient products and services clearly demonstrate the powerful guiding role of policy orientation on individual transformation, also facilitating the deep and widespread dissemination and absorption of the sustainable development concept, thereby constructing a reliable foundation for a comprehensively green modernization layout.

3 Theoretical Foundation

3.1 Carbon Emissions and Daily Life Behaviors

3.1.1 Definition and Sources of Carbon Emissions

Carbon emissions refer to the total amount of greenhouse gases directly or indirectly generated during production and living activities, including major greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Among these, carbon dioxide is considered the primary component due to its significant greenhouse effect, accounting for approximately 76% of global greenhouse gas emissions. To uniformly measure the environmental impact of different greenhouse gases, carbon emissions are generally expressed in terms of carbon dioxide equivalent (CO_2e),

standardizing the comparison of the impact levels of various greenhouse gases.

The sources of carbon emissions are diverse. Energy consumption, industrial manufacturing, agricultural production, land management, and waste disposal are all significant areas of carbon emissions. Large amounts of carbon dioxide are released into the atmosphere during various activities. In waste disposal processes, landfilling and wastewater treatment generate methane and carbon dioxide (Chen,2024). These diverse emission sources pose severe challenges to global climate change, making global-level emission reduction measures both necessary and crucial.

3.1.2 Classification of Daily Life Carbon Emission Behaviors

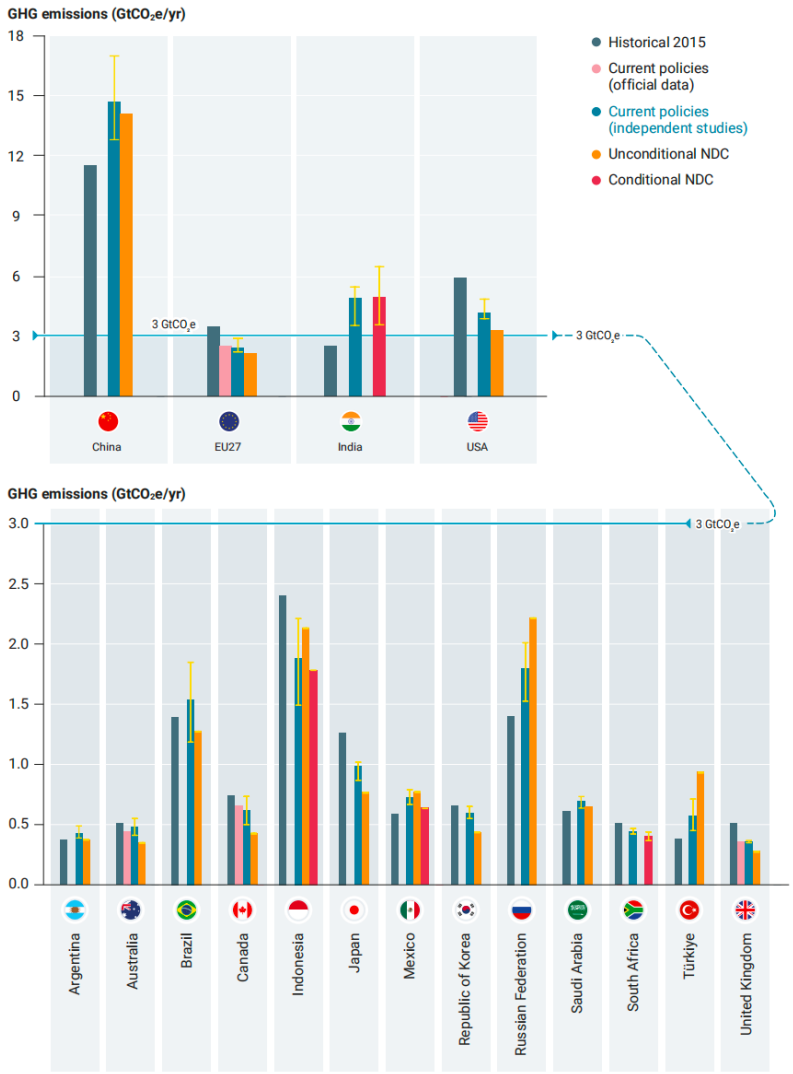

Figure 1 Emissions gap report

(Image source: https://www.unep.org/zh-hans/resources/2022nianpaifangchajubaogao?gclid=Cj0KCQiAj4ecBhD3ARIsAM4Q_jEovcmO_6j5bi9v5U6Bqyi0c5kTE2gquhfLVbUyig2FNzpcL3U1m8oaAqYSEALw_wcB)

Daily life carbon emission behaviors constitute an important part of individual carbon footprints. Their distribution characteristics and activity patterns directly impact the achievement of carbon neutrality goals. According to the United Nations Environment Programme's 2022 Emissions Gap Report, carbon dioxide emissions from household consumption

account for nearly 60% of the global total, with household carbon emission intensity in developed countries generally higher than in developing countries. Systematic analysis of daily carbon source structures reveals that energy use (approximately 45%~60%) is one of the primary sources, with high-energy-consuming appliances and heating facilities being major driving factors. The transportation sector accounts for about 20%, with significant variation depending on travel mode choices. Dietary habits cannot be overlooked; agricultural production and food waste together contribute to the food supply chain's overall emissions, reaching 26%, with livestock farming being particularly prominent. The impact throughout the product lifecycle of consumer goods must also be considered; the fast fashion industry consumes vast resources and emits significant greenhouse gases during manufacturing, while the second-hand market under the circular economy concept holds substantial emission reduction potential. The building operation phase occupies an important position, accounting for nearly 40%, where the level of fine management in residential areas plays a decisive role in reducing energy consumption per unit area. High-end lifestyle aspects such as international travel also require attention, as the carbon footprint of a single long-haul flight may far exceed the annual per capita average of some countries. These behaviors form an interconnected carbon emission network, providing a scientific pathway for precise emission reduction (Data sources: IPCC Special Reports, World Resources Institute database).

3.1.3 The Relationship Between Carbon Emissions and Sustainable Development

The primary environmental impact of carbon emission behaviors is global climate change. Excessive greenhouse gas emissions lead to rising global temperatures, triggering extreme weather events, sea-level rise, and biodiversity loss. These conditions not only harm the human living environment but also hinder sustained economic development. Therefore, reducing carbon emissions is a crucial step towards achieving sustainable development goals. Methods such as promoting low-carbon technologies and policies and enhancing public environmental awareness can effectively mitigate the impacts of climate change and propel the economy and society towards a greener, more sustainable direction.

3.2 Theory and Technology of Sound Visualization

Sound visualization technology is a technique that converts audio signals into visually perceivable images, allowing the presentation of important sound characteristics such as frequency, amplitude, and phase in visual form, thereby greatly enhancing people's ability to understand and analyze sound information. This innovative approach holds broad application prospects in fields such as music creation, acoustics, noise monitoring, and artistic expression, opening a new perspective for the analysis and presentation of sound.

The diversity of sound information extends far beyond visual presentation. Its core lies in demonstrating the close and profound relationship between sound and vision through sound-to-visual conversion, a process also known as visual sound translation. Sound plays a role in expressing linguistic meaning, leading to deeper explorations in semiotic hermeneutics, particularly regarding the mechanisms of meaning interpretation within logical formal systems.

In technical operation, sound visualization primarily relies on sensors to capture sound wave signals, convert them into electrical signals, analyze acoustic parameters using digital signal processing algorithms, and finally translate these parameters into different visual representations such as spectrograms, time-domain waveforms, and dynamic sonograms. This provides new analytical tools and expressive means for fields like music creation, noise monitoring, audio engineering, and artistic expression.

The technological development of sound visualization has progressed in stages. Early efforts primarily used

mechanical devices and analog signal processing methods. Due to limitations in hardware performance and computational power, the forms of sound visualization were relatively singular, and the effects were not ideal. Breakthroughs in computer science drove a significant transformation in the field, greatly improving data analysis accuracy and expanding the dimensions of visual presentation. In recent years, the combined role of big data and artificial intelligence has brought comprehensive innovation to the field. High-performance audio databases support efficient information extraction, while machine learning algorithms enable functionalities such as automatic classification, precise recognition, and real-time generation, substantially enhancing overall intelligence levels and practical application value. Currently, sound visualization technology is widely applied in the entertainment industry (music, film, and gaming), providing immersive artistic experiences, and is also used in scientific research, education, and other fields. Its main purposes include exploring the physical principles of sound and its interaction with the environment, disseminating scientific knowledge in intuitive forms, stimulating interest in technological innovation, and improving cognitive levels.

In the "Sound Poem" interactive design serving the hearing-impaired community, Tao Yuqi created a two-way sensory translation system aimed at using visualization methods to express the sensations evoked by music, allowing hearing-impaired individuals to better appreciate music(Tao Y Q, 2021). The design consists of two parts. The first is an audio-to-image conversion module that changes according to audio amplitude variations, generating corresponding images that transform intangible music into tangible visual symbols, directly presenting the emotions of the music. The second part is an image-to-sound reverse conversion mechanism where users select different notes via keyboard operations, the system generates corresponding sounds, and displays visual effects related to sound frequencies on the screen. This design provides a new avenue for hearing-impaired individuals to experience music and also offers a new direction for sound visualization.

The "Voice Drawing" App developed by Bai Xuejiao uses the FFT algorithm to analyze the spectrum and amplitude of sound signals, turning sound into a visual symbolic language and creating unique visual-theme works. Besides having broad application prospects in entertainment, education, art design, and other fields, the "Voice Drawing" APP can further improve user experience and interactivity through digital marketing, ASO, and SEM methods(Bai X J, 2024).

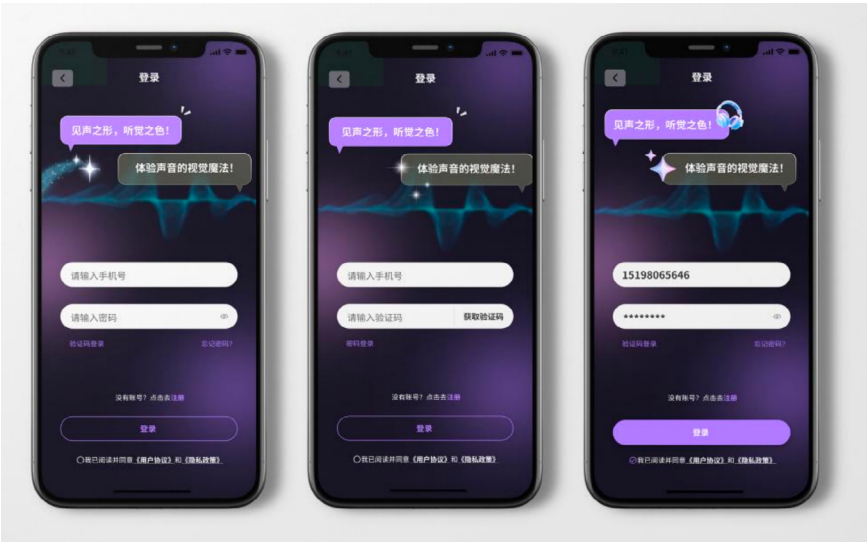

Figure 2 Voice drawing App interaction interface

(Image source: Research and Application of Sound Interaction Visualization)

In the field of intangible cultural heritage protection, Yang Xinyi combined sound visualization technology with the traditional craft of Xiashi Lantern Art to design an interactive installation integrating sound and vision. Using the TouchDesigner platform, a sound-light interactive device was constructed By capturing sound frequency and amplitude parameters in real-time, the brightness, color, and motion effects of the lantern art were dynamically adjusted, creating an immersive artistic experience and providing a new path for the living transmission of intangible cultural heritage(Yang X Y, 2025).

Ling Yan converted the audio characteristics of white noise into abstract geometric shapes by analyzing its audio features. This research not only explored the connection between sound and geometric forms but also visualized the imagery of white noise through design, transforming white noise audio data into visual elements such as points, lines, and planes, thereby presenting the natural and balanced beauty of white noise to the audience(Ling Y, 2019). Visual music graphics are based on visual perception, and their design follows aesthetic principles. Through visual perception, they skillfully integrate form, vision, and connotation, achieving the effective transformation of music into visual art(Li J T, 2023). From an artistic perspective, such design reflects the aesthetic significance embedded in sound visualization and provides audiences with novel visual experiences, making the imagery of white noise more vivid and tangible.

Therefore, sound visualization technology has developed into a significant driver of design innovation. Its extensive use in improving interactive experiences, transmitting cultural heritage, and expanding artistic language offers unprecedented new opportunities and developmental space for design practice.

4 Application of Sound Visualization in Visual Communication Design and Creation

4.1 Sound Visualization Creative Concepts Integrating Ecological Principles

Compared to traditional two-dimensional graphic design methods, integrating digital media technology into the realm of three-dimensional modeling design has become a key avenue for the convergence of visual art and technological innovation, demonstrating strong originality and expressive power (Niu S X, 2024). This research further incorporates the concept of ecological symbiosis, focusing on the deep connections between design systems and the natural environment, prompting visual expression to shift from formal exploration towards ecological value construction. Based on a comprehensive understanding of sound visualization technology, this study selected nine common carbon emission scenarios as key subjects. With the aid of interactive software, it conducted abstract extraction and dynamic reorganization of acoustic signals and image data. Methods like spectral diagrams and information graphics were used to create dynamic forms of visualization. Combined with multimedia elements, a multi-channel narrative framework was established to enhance emotional appeal and cognitive depth in communication.

Within the field of graphic visual communication design, pixelated language, relying on the “lightweight” and “pollution-free” attributes inherent in its digital characteristics, aligns with the essential needs of the low-carbon concept, achieving deep integration of formal expression and ecological value. From a creative perspective, emphasis

was placed on optimizing the design of interactive experiences, guiding audiences to intuitively perceive the impact of various carbon emission behaviors through simple operations and obtain instant audiovisual feedback. Through a concise yet emotionally charged graphic symbol system, abstract data was transformed into concrete audiovisual narratives. The goal was to increase public enthusiasm for participating in environmental protection actions and jointly promote the achievement of global climate governance goals.

4.2 Creative Practice

This study first conducted a visual abstraction of nine typical carbon emission behaviors, forming a unified graphic symbol system. These symbols were then applied to video creation and main visual design. In multimedia production, the Touch Designer platform was used to translate audio signals, combined with thermal imaging technology to adjust color schemes, resulting in nine dynamic visualization sequences with educational and aesthetic value. In graphic design, pixelated expression techniques were employed, using the "lightweight" characteristics of digitalization to interpret the low-carbon concept. Virtual pixel images were fused with real-scene photography to directly display the quantitative relationship between greenhouse gas emissions and global climate change, deepening audience understanding and enhancing emotional resonance.

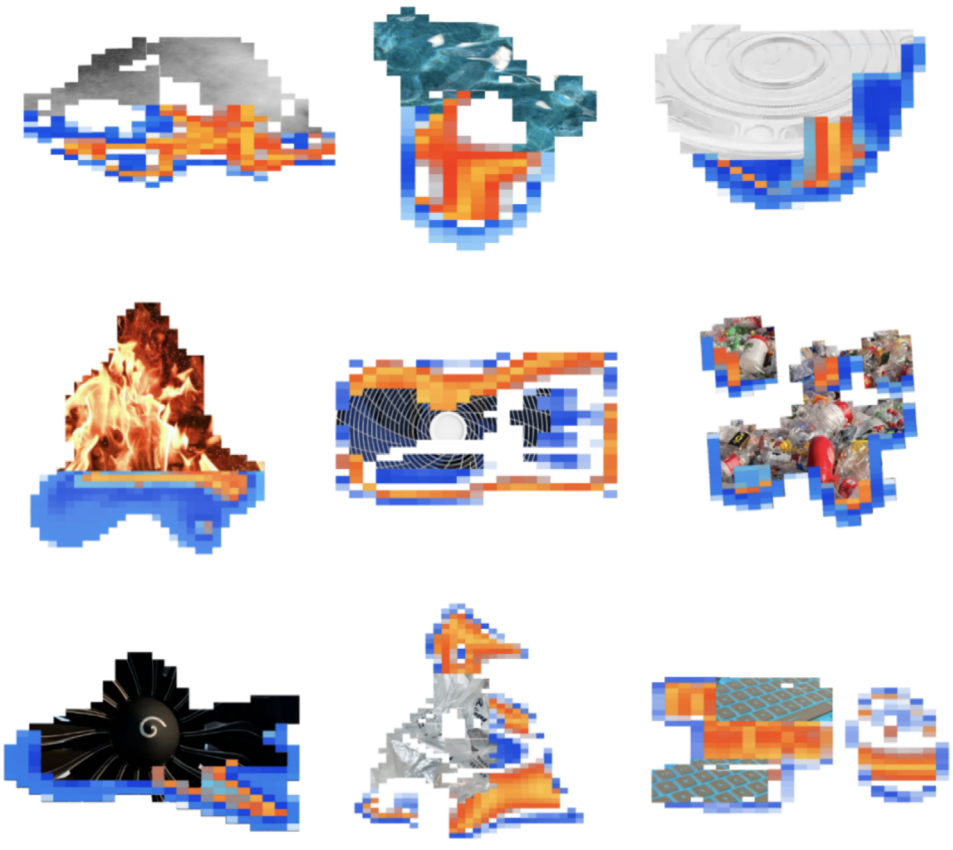

Figure 3 Visual Elements

(Image source: Self-made)

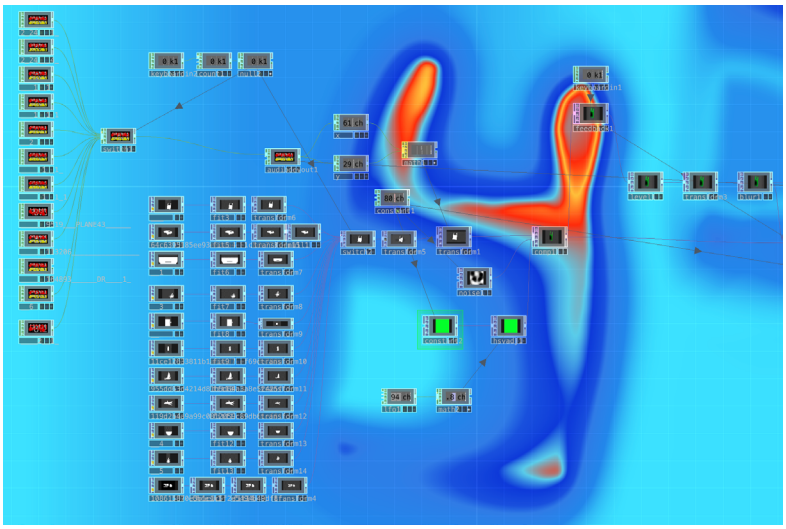

Figure 4 Video Production

(Image source: Self-made)

Figure5 Video screenshot

(Image source: Self-made)

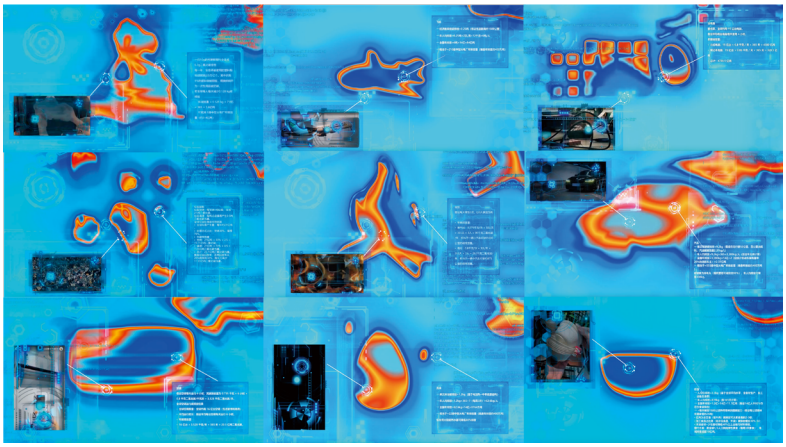

Figure6 Video screenshot

(Image source: Self-made)

During the visual element integration phase, graphic symbols were systematically arranged and applied to scenarios such as main visual posters and derivative product design. To make information transmission more effective and persuasive, data from the nine carbon emission behaviors was used as the foundational element for a chart card identification system, constructing a comprehensive communication system architecture based on interactive videos.

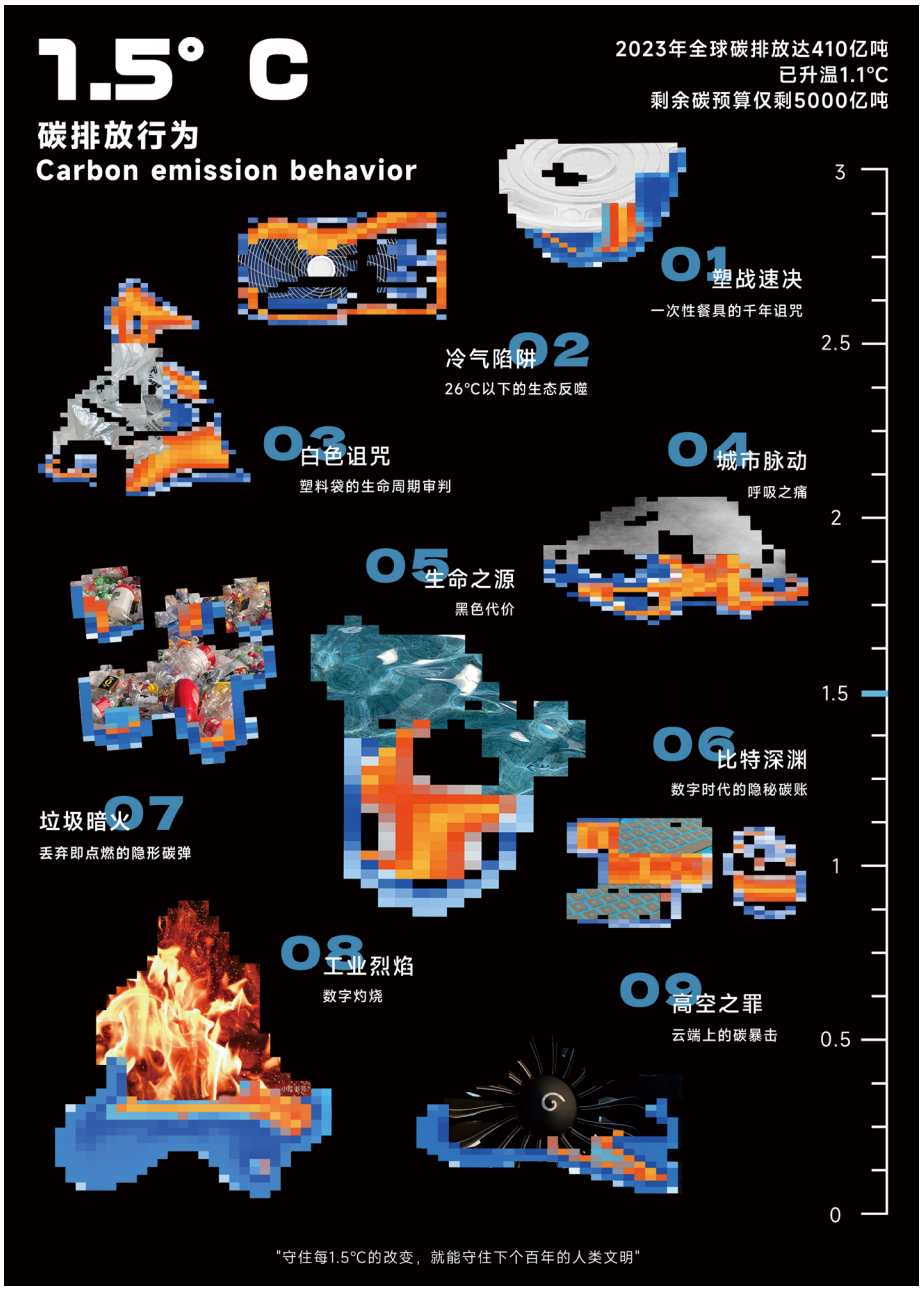

Figure 7 Main visual poster

(Image source: Self-made)

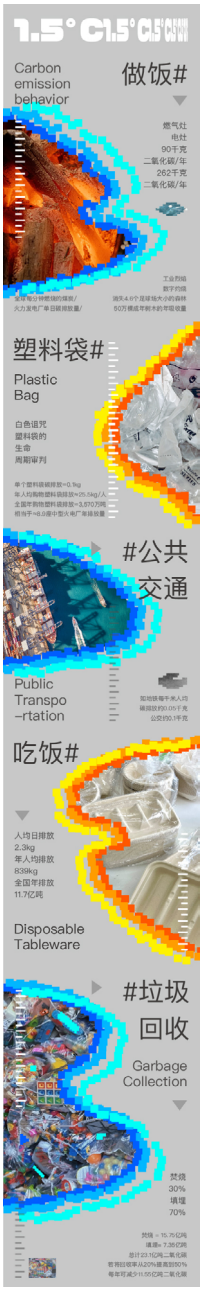

Figure 8 Long scroll image

(Image source: Self-made)

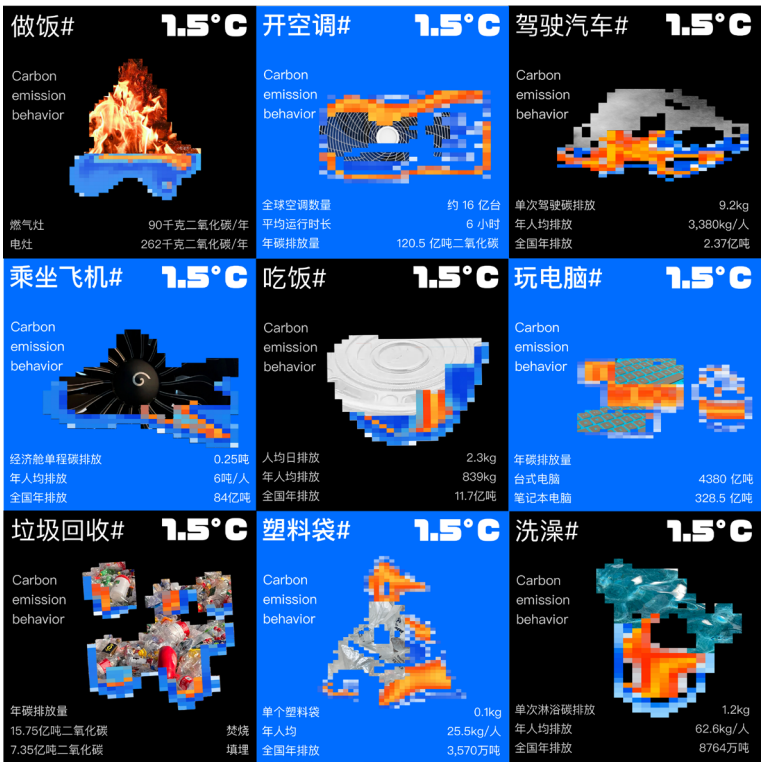

Figure 9 Information card

(Image source: Self-made)

Figure 10 Informational diagram

(Image source: Self-made)

This study, under the theme “1.5°C - Carbon Emission Sound Visualization Experience Exhibition,” used sound visualization technology to transform nine types of daily carbon emission behaviors into immersive audiovisual

experiences. Orange tape was used in the exhibition space for visual guidance, aligning with the theme while serving a warning function. The core exhibition area consisted of nine acrylic information boards and a looped video. Translucent film posters enhanced the sense of flow of carbon emissions. The interactive area used exposed steel frames and polycarbonate panels to represent the integration of industry and nature, accompanied by graphic guides to impart emission reduction knowledge. The entire exhibition, relying on multi-channel perceptual design encompassing vision, hearing, and touch, enhanced public engagement and educational communication effectiveness. The unity of artistic expression and scientific data was also achieved.

Figure 11 On-site work photography (1)

(Image source: Self-made)

Figure 12 On-site work photography (2)

(Image source: Self-made)

Figure 13 On-site work photography (3)

(Image source: Self-made)

5 Conclusion

At the intersection of the "dual carbon" strategy and the concept of ecological civilization integration, this paper conducted research on the design practice of applying sound visualization technology to represent carbon emission behaviors, establishing an innovative transformation pathway from behavior to data, data to sound, and sound to visual art. By representing nine typical carbon emission activities through strongly narrative and emotionally impactful audiovisual works, it was demonstrated that cross-sensory design strategies can significantly enhance public cognition of carbon emissions. This also provides new ideas and pathways for visual communication design in disseminating environmental information and advocating low-carbon lifestyles.

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