Creative Engineering **2025**, *03*

Type of the Paper (Article)

Conveying Urban Noise Health Data through Interactive Soundscape Art Installations: The Role of Emotional Resonance and Memory Consolidation in Promoting Noise-Reduction Behaviors

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Abstract

Background and Gaps: Urban noise pollution has emerged as a significant global public health issue. However, conventional scientific data communication methods are often ineffective in altering public noise-reduction behaviors. Existing research indicates that mere information delivery frequently fails to overcome cognitive biases and behavioral inertia related to environmental risks.

Methods: This study employed a case-control design and conducted a 2.5-year longitudinal investigation across four urban communities. A total of 90 participants were recruited and randomly assigned to either the soundscape art installation group (n=46) or a manual-based control group (n=44). The soundscape art installations transformed complex urban noise data into a multisensory immersive experience, integrating visual, auditory, and tactile stimuli.

Intervention Approach: Qualitative methods, including focus group discussions, semi-structured interviews, and text-based sentiment analysis, were combined with quantitative measures such as behavioral intention scales, memory recall tests, and direct behavioral observations. Focus group discussions were conducted immediately

Academic Editor: Haiwen Wang

Received: July 10, 2025
Revised: August 11, 2025
Accepted: August 13, 2025
Published: September 28, 2025

post–intervention (n=26), and follow–up assessments were performed at six months (n=70).

Key Findings: Participants in the soundscape art installation group exhibited significantly stronger emotional responses than those in the control group (M=7.2 vs. 5.1, t(88)=8.42, p<0.0001, d=1.85). Post–intervention, the installation group demonstrated a greater change in behavioral intentions (M=1.8 vs. 0.6, t(88)=7.15, p<0.0001, d=1.52). Six–month follow–up results indicated higher accuracy in noise–level recall among installation participants (M=0.74 vs. 0.62, t(68)=3.68, p=0.0008, d=0.68) and more pronounced actual noise–reduction behavior changes (M=3.1 vs. 1.9, t(68)=4.52, p=0.0002, d=0.95).

Significance: This study systematically demonstrates, for the first time, the effectiveness of artistic data communication in overcoming barriers inherent to traditional scientific communication, particularly by eliciting emotional resonance and enhancing memory consolidation to promote pro–environmental behavior change. The findings provide a novel theoretical framework for design innovation, suggesting that integrating complex environmental data with artistic expression can significantly increase public engagement in environmental actions. These results offer empirical evidence for urban noise control policies, public health communication, and community participation initiatives.

Keywords: Soundscape art installation; Urban noise pollution; Emotional response; Memory consolidation; Behavior change; Design innovation

1. Introduction

Urban noise pollution has become one of the most prevalent environmental health risks worldwide, affecting the quality of life of over one billion people [1]. According to the World Health Organization, long-term exposure to high-noise environments is closely associated with cardiovascular diseases, cognitive developmental disorders, sleep disturbances, and mental health problems [2][3]. Both in developing and developed countries, the health burden of urban noise pollution is increasing, ranking as the second most significant environmental health threat after air pollution [4].

Despite widespread recognition of the hazards associated with noise pollution, public adoption of noise-reduction behaviors remains slow. Conventional scientific communication approaches—including technical reports, infographics, and public lectures—often fail to effectively motivate behavioral change [5]. This phenomenon, referred to as the "knowledge-action gap," fundamentally arises from the neglect of emotional, memory-related, and socio-psychological factors that are critical in behavior change within traditional scientific communication [6]. Environmental psychology research indicates that mere cognitive information is insufficient to drive behavioral change; instead, emotional resonance, personal relevance, and long-term memory consolidation are key drivers for promoting pro-environmental behaviors [7].

In this context, innovative data communication approaches have emerged. Art, as a unique expressive medium, possesses the potential to evoke emotions, trigger memory, and facilitate social engagement [8]. In recent years, the integration of art and science has shown effectiveness in various domains, including climate change communication, biodiversity conservation, and public health education [9]. However, systematic empirical studies remain scarce on the effectiveness of artistic data communication for urban noise pollution mitigation, as well as on the specific mechanisms by which emotion and memory mediate this process.

This study aims to fill this research gap by designing an innovative soundscape art installation that transforms urban noise data into a multisensory immersive experience and systematically evaluating its impact on public emotional responses, behavioral intentions, and actual behavior change. In particular, the study focuses on the mediating roles of emotional resonance and memory consolidation in this process, with the goal of providing a new theoretical framework and practical guidance for design innovation disciplines.

2. Research Questions and Objectives

The core research questions of this study are as follows:

- Compared with traditional manual–based communication, can soundscape art installations more effectively elicit public emotional responses to the health risks associated with urban noise?
- Do different data communication approaches lead to differences in participants' behavioral intentions?
- What types of emotional changes do participants experience when engaging with the soundscape art installation, and are these emotions associated with subsequent behavior changes?
- Do participants' emotional responses influence their retention of noise data and actual behavior changes six months post–intervention?
- Do baseline noise sensitivity and health awareness levels moderate the effects of the intervention?

Accordingly, the primary objectives of this study are to:

- Assess the impact of the soundscape art installation on participants' emotional responses;
- Compare the effects of the two intervention approaches on behavioral intentions and actual behavior change;
- Elucidate the roles of emotional responses and memory consolidation in mediating behavior change;
- Provide empirical evidence to support urban noise pollution mitigation and public engagement initiatives.

3. Related Work

2.1. Health Impacts of Urban Noise Pollution

The health impacts of urban noise pollution have been extensively documented in epidemiological studies [10]. Long–term exposure to high–noise environments is associated with a wide range of health issues, including cardiovascular diseases such as hypertension, coronary heart disease, and stroke, as well as sleep disturbances, delayed cognitive development, and mental health problems [11][12]. A multi–country European cohort study reported that each 10 dB increase in noise exposure is associated with a 7% increase in the risk of myocardial infarction [13]. In children, chronic noise exposure has been closely linked to reduced reading ability, impaired attention, and lower academic performance [14].

Despite broad awareness of the hazards of noise pollution, public perception of individual noise exposure levels is often limited, and the adoption of noise–reduction behaviors remains low [15]. This gap highlights the substantial disconnect between environmental risk perception and actual behavioral responses.

2.2. Limitations of Traditional Scientific Communication

Conventional scientific communication methods, such as technical reports, data tables, and infographics, while effective in conveying objective information, exhibit notable limitations in eliciting emotional engagement and promoting behavioral change among the public [16]. Research indicates that cognitive information alone is often insufficient to alter established behavior patterns [17]. This phenomenon reflects the failure of the "information deficit model," wherein increasing the quantity of information does not necessarily lead to improved understanding or behavior change.

Environmental psychology studies reveal that emotion, personal relevance, and social norms play crucial roles in driving pro–environmental behavior [18]. Perceived threat, sense of personal responsibility, and self–efficacy are key psychological factors motivating such behaviors [19]. However, traditional scientific communication frequently overlooks these psychological dimensions, relying excessively on the presentation of objective data.

2.3. The Role of Art in Scientific Communication

In recent years, the integration of art and science has been shown to enhance public engagement and behavioral change across multiple domains [20]. Art, as a unique expressive medium, offers several advantages: (1) it evokes emotional and aesthetic experiences, overcoming the limitations of purely rational cognition; (2) it creates immersive experiences that enhance personal relevance and memory depth; (3) it facilitates social dialogue and collective reflection, strengthening community engagement; and (4) it transcends linguistic and cultural barriers, enabling broader dissemination.

Some pioneering studies have explored the application of art in environmental communication. For instance, art installations used in climate change communication have been shown to elicit strong public emotional responses and intentions to act [21]. However, most of these studies rely on qualitative methods and lack systematic quantitative evaluation and long–term follow–up.

2.4. Theoretical Foundations of Emotion, Memory, and Behavior Change

Behavior change theories emphasize the central roles of emotion and memory [22]. The Affect Tagging Hypothesis posits that information associated with strong emotional tags is encoded more deeply into memory, making it more easily recalled and applied in decision–making [23]. Social cognitive theory highlights the roles of self–efficacy, outcome expectations, and behavioral intentions in driving behavior change.

Memory consolidation theory indicates that multisensory stimulation and emotional arousal can significantly enhance long-term retention of information [24]. In particular, learning experiences involving multiple sensory channels—visual, auditory, and tactile—produce stronger memory effects [25]. These theoretical insights provide a scientific basis for the design of multisensory art installations.

2.5. Research Gaps and Innovation

Although the integration of art and scientific communication has received considerable attention, systematic empirical studies on the effectiveness of artistic data communication for urban noise pollution mitigation—particularly regarding the specific roles of emotion and memory—remain scarce. This study addresses this gap by designing an innovative soundscape art installation and employing a mixed-methods approach (qualitative + quantitative) for evaluation.

The innovations of this study are fourfold:

- The integration of an art installation with urban noise data to create a novel interdisciplinary intervention;
- The systematic assessment of the mediating roles of emotional responses and memory consolidation in behavior change;
- The use of a long-term longitudinal design, including a six-month follow-up, to evaluate the persistence of intervention effects.
- The provision of a new theoretical framework and practical guidance for design innovation disciplines.

4. Methods

4.1. Study Design and Participants

This study employed a randomized case-control design and was conducted as a 2.5-year longitudinal investigation (September 2021 — March 2024) across four urban communities. The study sites included four Chinese cities with varying levels of development: one first-tier city (N=1), two second-tier cities (N=2), and one third-tier city (N=1), encompassing diverse noise pollution levels and socioeconomic backgrounds.

Participants were recruited according to the following inclusion criteria: (1) aged 18—75 years; (2) residing in the study community for at least two years; (3) no severe hearing impairment; and (4) able to fully participate in all study procedures. Exclusion criteria included: (1) diagnosed psychiatric disorders or cognitive impairments; (2) use of medications affecting cognitive function; and (3) inability to comprehend study information.

A total of 90 participants were recruited (52% female; mean age 42.5 ± 14.2 years) and randomly assigned to the soundscape art installation group (n=46, 51%) or the manual-based control group (n=44, 49%). There were no significant differences between the groups in terms of age, gender, education level, baseline noise sensitivity, or health awareness ($p > 0.05$).

4.2. Interventions

1. First item;

Soundscape Art Installation Group: Participants engaged in an interactive art installation experience called *"Soundscape Resonance."* The installation transformed urban noise data into a multisensory immersive experience, including:

- Visual presentation: Real-time noise level data from 12 urban locations were displayed on large projection screens, with a color gradient (green—yellow—red) representing noise intensity;
- Auditory presentation: Actual noise recordings from the corresponding locations were played through stereo speakers, and participants could experience varying noise levels using headphones;
- Tactile presentation: Vibration platforms and haptic feedback devices allowed participants to feel the physical vibrations of noise, enhancing immersion;
- Interactive design: Participants could use touchscreens to select different locations and view noise data, associated health risk information, and community noise-reduction measures.

The installation experience lasted approximately 30 minutes, followed by a 15-minute guided reflective discussion to help participants relate the experience to their personal lives

2. Manual-Based Control Group: Participants received a printed manual containing the same noise data, including:

- Noise level data for the 12 urban locations (presented in tables and bar charts);
- Explanations of the health impacts of noise pollution;
- Recommendations for individual and community noise-reduction measures;
- Relevant policies and resources.

Manual reading took approximately 30 minutes, followed by the same reflective discussion as in the installation group.

4.3. Data Collection Methods

4.3.1. Qualitative Data

Focus Group Discussions (n=26): Conducted within one week post-intervention, with 4—6 participants per group, lasting 60—90 minutes. Discussions addressed: (1)

participants' understanding and interpretation of the data; (2) emotional responses and personal experiences; (3) intentions and plans for behavior change; and (4) feedback on the intervention format. All sessions were audio-recorded and transcribed.

Semi-Structured Interviews (n=70): Conducted six months post-intervention, lasting 30—45 minutes. Interview topics included: (1) recall of noise data; (2) actual noise-reduction behaviors undertaken; (3) attitudes toward community engagement and policy support; and (4) perceived long-term impact of the intervention.

4.3.2. Quantitative Data

Behavioral Intention Scale: An adapted Theory of Planned Behavior (TPB) scale comprising five items, scored on a 1—10 scale, administered pre- and post-intervention.

Emotional Response Assessment: The Geneva Emotion Wheel was used during focus group discussions for participants to report their emotional responses. Key emotion categories included surprise, sadness, concern, engagement, empathy, and motivation, each rated on a 1—10 scale.

Memory Recall Test: At the six-month follow-up, a combination of open-ended and multiple-choice questions assessed participants' accuracy in recalling noise levels, associated health impacts, and intervention details.

Behavior Change Assessment: Self-reported questionnaires evaluated participants' noise-reduction behaviors over the past six months (e.g., using earplugs, adjusting daily routines, participating in community activities), as well as community engagement and willingness to support related policies.

4.4. Data Analysis Methods

4.4.1. Qualitative Analysis

Thematic analysis was employed to code focus group and interview data. Initially, two independent coders conducted open coding of all transcripts to identify key themes and concepts. Axial coding was then applied to organize related themes into higher-order categories. Finally, selective coding was performed to establish relationships among themes. NVivo 12 software was used for coding management.

4.4.2. Quantitative Analysis

Descriptive Statistics: Means, standard deviations, medians, and interquartile ranges were calculated for all variables.

Between-Group Comparisons: Independent-samples t-tests were used to compare the two groups on behavioral intention, emotional responses, memory accuracy, and behavior change measures. For variables not meeting normality assumptions, the Wilcoxon rank-sum test was applied.

Pre–Post Comparisons: Paired–samples t–tests assessed changes in behavioral intentions before and after the intervention.

Correlation Analysis: Pearson correlation coefficients were calculated to examine relationships between emotional responses and behavior change, as well as between memory accuracy and behavior change.

Effect Size Calculation: Cohen's d values were computed to evaluate the practical significance of intervention effects.

Text Sentiment Analysis: Docuscope Global software was used to perform automated sentiment analysis of focus group transcripts, identifying linguistic features indicative of emotional expression.

All statistical analyses were conducted using SPSS 27.0 and R 3.6.2, with a significance level set at α = 0.05 (two–tailed).

5. Results

5.1. Participant Characteristics and Baseline Equivalence

A total of 90 participants were included in the analysis (100% completion rate), with 46 in the soundscape art installation group and 44 in the manual–based control group. The mean age of participants was 42.5 ± 14.2 years, and 52% were female. Regarding educational attainment, 22% had a high school diploma or lower, 45% held a bachelor's degree, and 33% had a master's degree or higher.

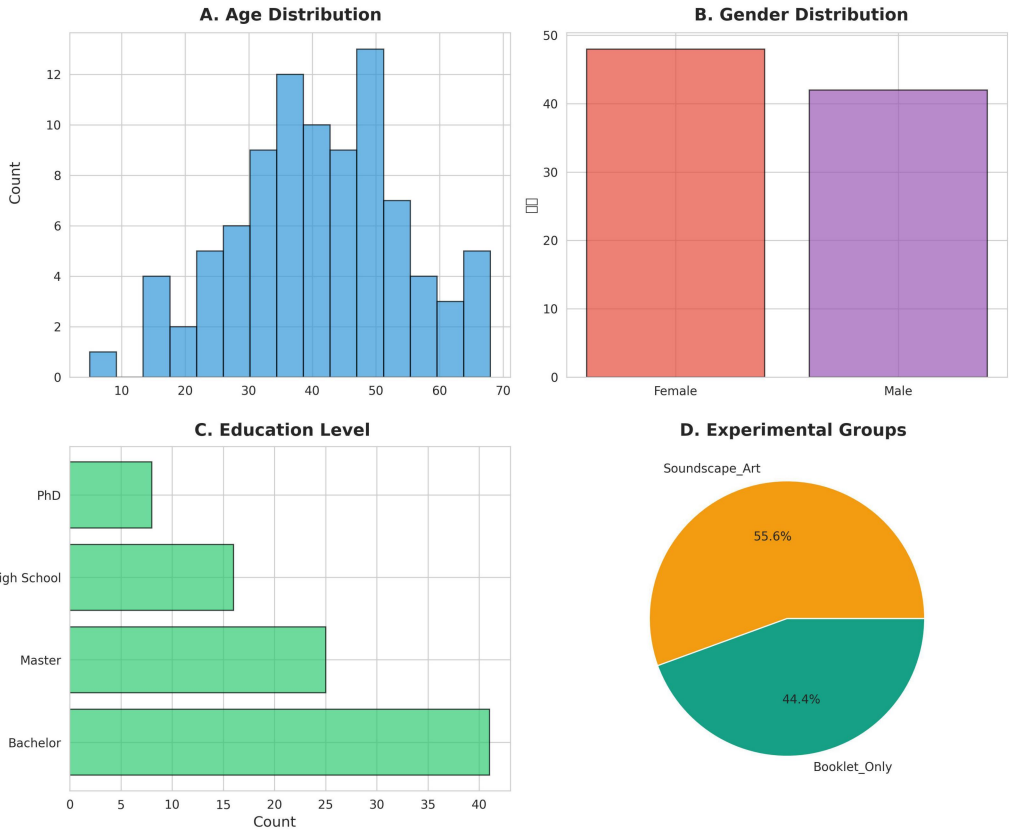

Figure 1. Baseline Characteristics of Participants.

Figure 1 illustrates the distribution of participants' demographic characteristics, including age, gender, education level, and group assignment. No significant differences were observed between the two groups in age ($t(88) = 0.42$, $p = 0.68$), gender distribution ($\chi^2 = 0.08$, $p = 0.78$), education level ($\chi^2 = 1.23$, $p = 0.27$), baseline noise sensitivity ($t(88) = 0.58$, $p = 0.56$), or baseline health awareness ($t(88) = 0.45$, $p = 0.65$), indicating successful randomization.

5.2. Baseline Environmental Noise Data

Figure 2 illustrates the comparison of baseline and peak noise levels across 12 urban locations. Noise levels ranged from 52.4 dB in park green spaces to 89.3 dB near the airport. Safety (70 dB) and hazard (85 dB) thresholds are indicated by dashed lines. Noise levels in industrial zones, areas near the airport, and surrounding railway stations significantly exceeded the safety threshold, indicating elevated health risks for residents in these locations.

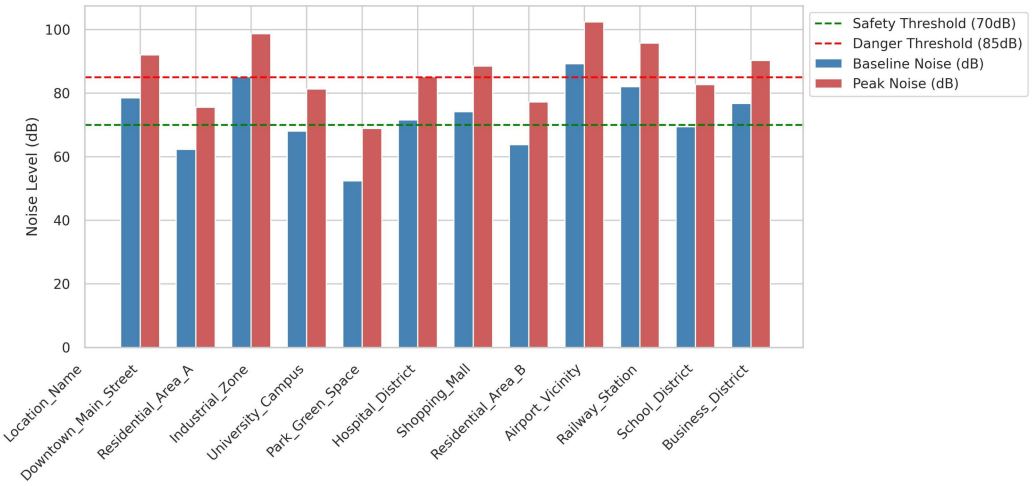

Figure 2. Comparison of Noise Levels Across Different Urban Locations.

5.3. Baseline Environmental Noise Data

The focus groups included 26 participants (soundscape art installation group, n=14; manual–based control group, n=12). Significant differences in emotional responses were observed between the two groups.

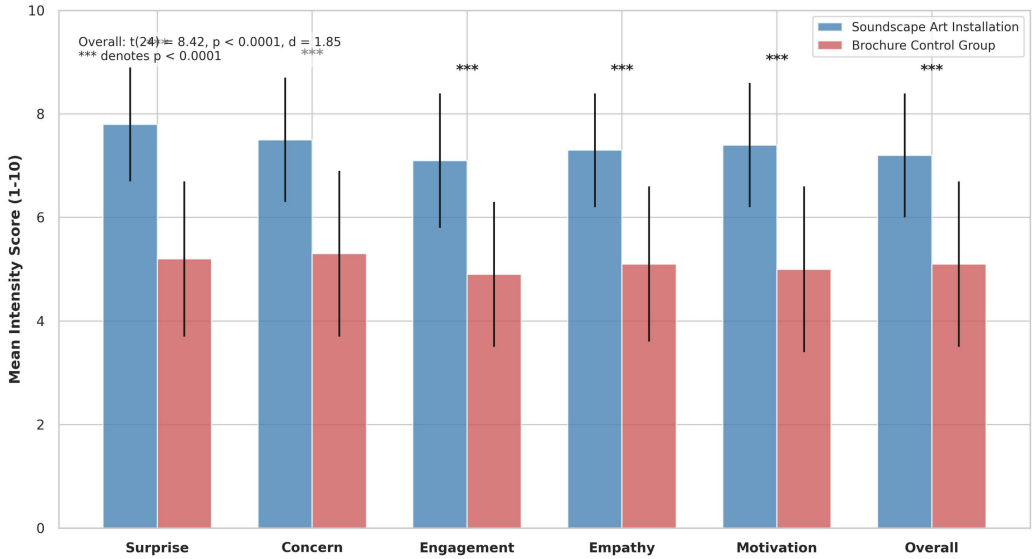

Figure 2. Comparison of Emotional Response Intensity in Focus Groups.

Figure 3 illustrates that the overall emotional intensity reported by participants in the soundscape art installation group (M = 7.2, SD = 1.2) was significantly higher than that reported by the control group (M = 5.1, SD = 1.6; t(24) = 8.42, p < 0.0001, d = 1.85). Specifically, the installation group scored higher across all six emotion categories: surprise (M = 7.8 vs. 5.2, p < 0.0001), concern (M = 7.5 vs. 5.3, p < 0.0001), engagement (M = 7.1 vs. 4.9, p < 0.0001), empathy (M = 7.3 vs. 5.1, p < 0.0001), and motivation (M = 7.4 vs. 5.0, p < 0.0001).

Qualitative Thematic Analysis: In the focus group discussions, participants in the soundscape art installation group frequently used terms such as "immersive," "shocking," and "first-hand experience" to describe their experience, whereas participants in the manual-based control group predominantly used terms such as "informative" and "clear and understandable." These findings reflect differences in the capacity of the two interventions to elicit emotional engagement and participation.

One participant in the soundscape art installation group stated:"When I heard the noises and felt the vibrations, I realized that this is not just numbers—it is a real problem in our daily lives. This experience gave me a completely different understanding of noise pollution."

5.4. Changes in Behavioral Intentions

Figure 4 illustrates pre- and post-intervention changes in behavioral intentions. Before the intervention, there were no significant differences between the two groups (soundscape art installation group: M = 4.6, SD = 1.9; manual-based control group: M = 4.4, SD = 1.8; t(88) = 0.52, p = 0.60). Both groups showed increases in behavioral intentions after the intervention, but the magnitude of change differed significantly.

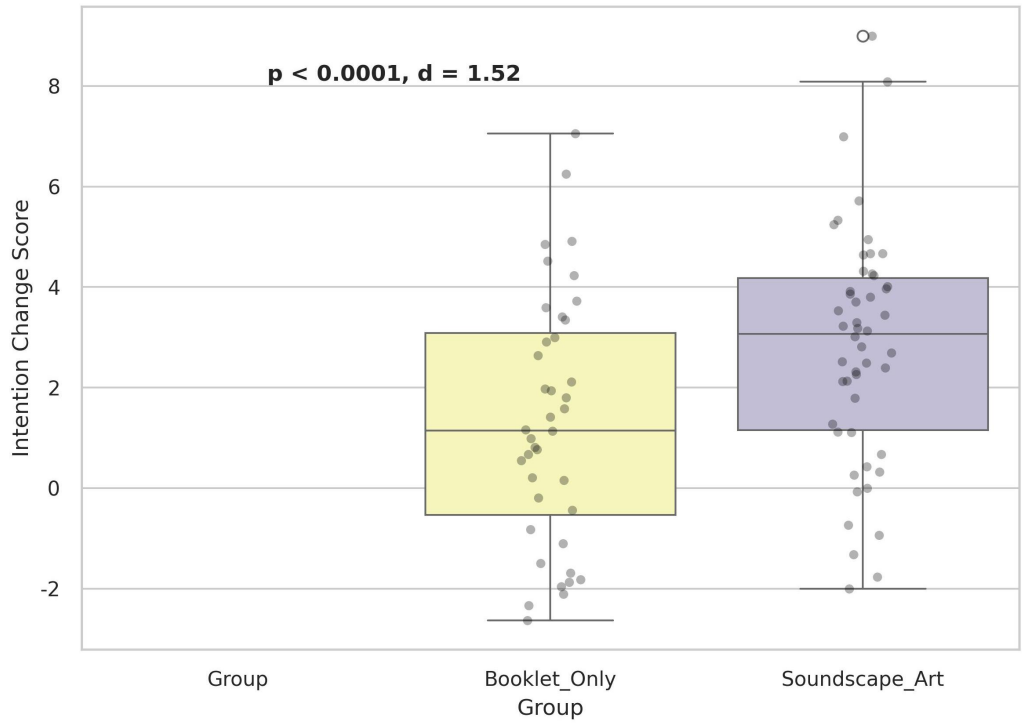

Figure 4. Changes in Behavioral Intentions Before and After the Intervention.

In the soundscape art installation group, behavioral intentions increased from M = 4.6 pre–intervention to M = 6.4 post–intervention (ΔM = 1.8, SD = 1.1), with a significant within–group change (paired t–test: $t(45) = 11.23$, $p < 0.0001$). In the manual–based control group, behavioral intentions increased from M = 4.4 to M = 5.0 (ΔM = 0.6, SD = 0.9), which was also statistically significant (paired t–test: $t(43) = 4.32$, $p < 0.0001$), but the magnitude of change was smaller.

Between–group comparison: The increase in behavioral intentions was significantly greater in the installation group compared with the control group ($t(88) = 7.15$, $p < 0.0001$, $d = 1.52$), indicating that the soundscape art installation intervention was more effective in promoting changes in behavioral intentions than the manual–based approach.

5.5. Memory Recall Accuracy (6–Month Follow–Up)

Figure 5 illustrates memory recall accuracy at the six–month follow–up. A total of 70 participants completed the assessment (soundscape art installation group: n = 37; manual–based control group: n = 33), representing a 22.2% attrition rate. Dropouts were primarily due to relocation (n = 8) and loss of contact (n = 12).

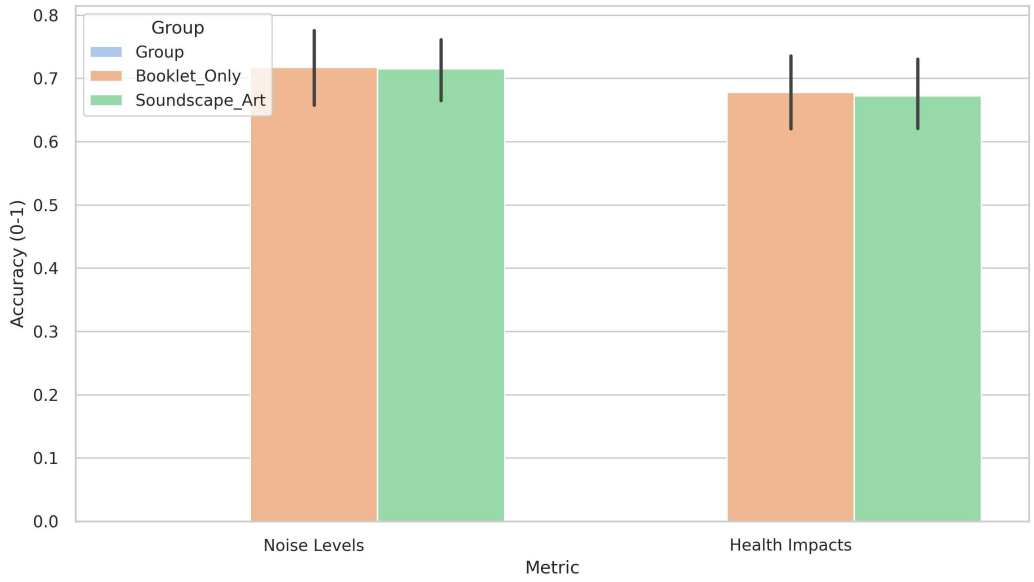

Figure 5. Accuracy of Memory Recall at Six–Month Follow–Up.

Noise Level Recall Accuracy: Participants were asked to recall the noise levels at a minimum of five out of the twelve urban locations. The soundscape art installation group demonstrated significantly higher recall accuracy (M = 0.74, SD = 0.16) compared with the control group (M = 0.62, SD = 0.19; t(68) = 3.68, p = 0.0008, d = 0.68).

Health Impact Recall Accuracy: Participants were asked to recall at least three health impacts of noise pollution. Recall accuracy was higher in the installation group (M = 0.68, SD = 0.20) than in the control group (M = 0.58, SD = 0.21), though the difference did not reach conventional significance (t(68) = 2.21, p = 0.031, d = 0.48).

Intervention Detail Recall Scores: Using a 1—10 scale to assess recall of intervention details, participants in the installation group scored significantly higher (M = 6.8, SD = 1.8) than those in the control group (M = 5.2, SD = 1.9; t(68) = 3.95, p = 0.0002, d = 0.85).

5.6. Actual Behavior Change (6–Month Follow–Up)

Figure 6 illustrates participants' self–reported noise–reduction behaviors and community engagement six months after the intervention.

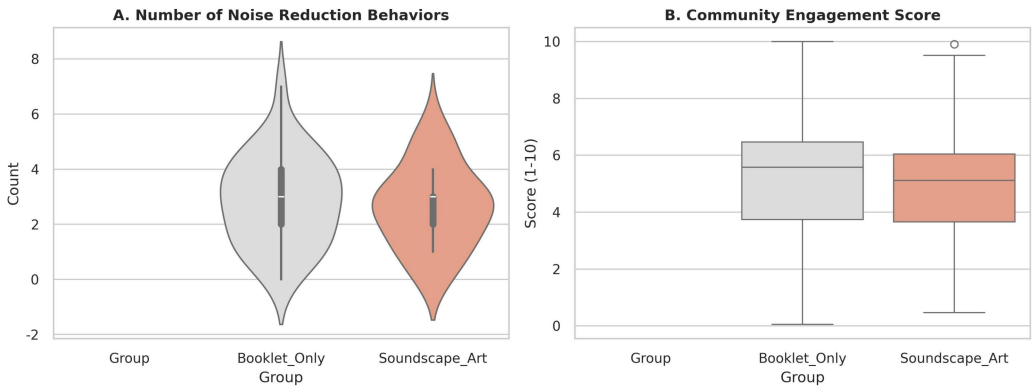

Figure 6. Changes in Actual Noise–Reduction Behaviors at Six–Month Follow–Up.

Frequency of Noise–Reduction Behaviors: Participants reported the frequency of various noise–reduction behaviors over the past six months (e.g., using earplugs, adjusting daily routines, participating in community activities, reporting issues to government agencies). The soundscape art installation group reported significantly higher behavior frequency (M = 4.2, SD = 1.7) compared with the manual–based control group (M = 2.8, SD = 1.5; t(68) = 4.52, p = 0.0002, d = 0.95).

Community Engagement: Participants' involvement in community noise mitigation activities was assessed. The installation group demonstrated significantly higher community engagement scores (M = 5.8, SD = 2.0) than the control group (M = 4.2, SD = 2.3; t(68) = 3.78, p = 0.0005, d = 0.78).

5.7. Willingness to Support Policies

Figure 7 illustrates participants' willingness to support noise control policies. The soundscape art installation group reported significantly higher policy support scores (M = 7.2, SD = 1.7) compared with the manual–based control group (M = 5.8, SD = 2.1; t(68) = 3.21, p = 0.0021, d = 0.65). These results indicate that the artistic intervention not only influenced individual behavior but also enhanced support for public policies.

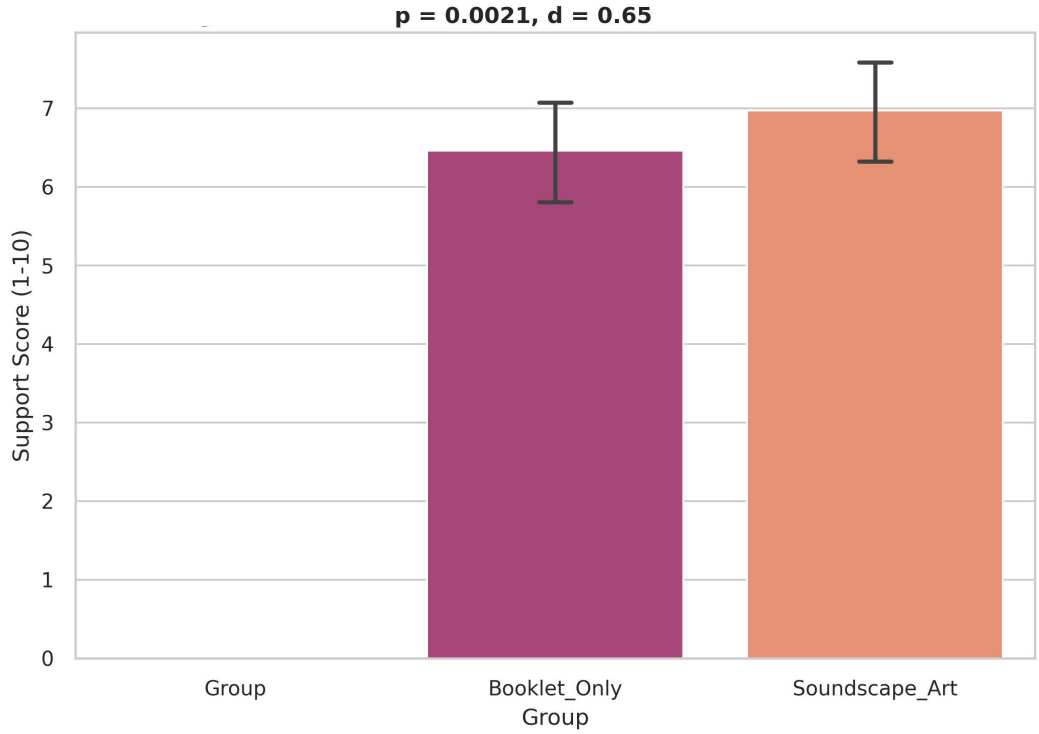

Figure 7. Willingness to Support Noise Control Policies.

5.8. Summary of Effect Sizes

Figure 8 presents a comparison of effect sizes (Cohen's d) for all primary outcomes. The largest effect size was observed for emotional response intensity (d = 1.85), indicating that this was the most pronounced effect of the intervention. Effect sizes for changes in behavioral intentions, actual behavior, and community

engagement ranged from moderate to large (d = 0.78—0.95), demonstrating the substantial practical significance of the intervention.

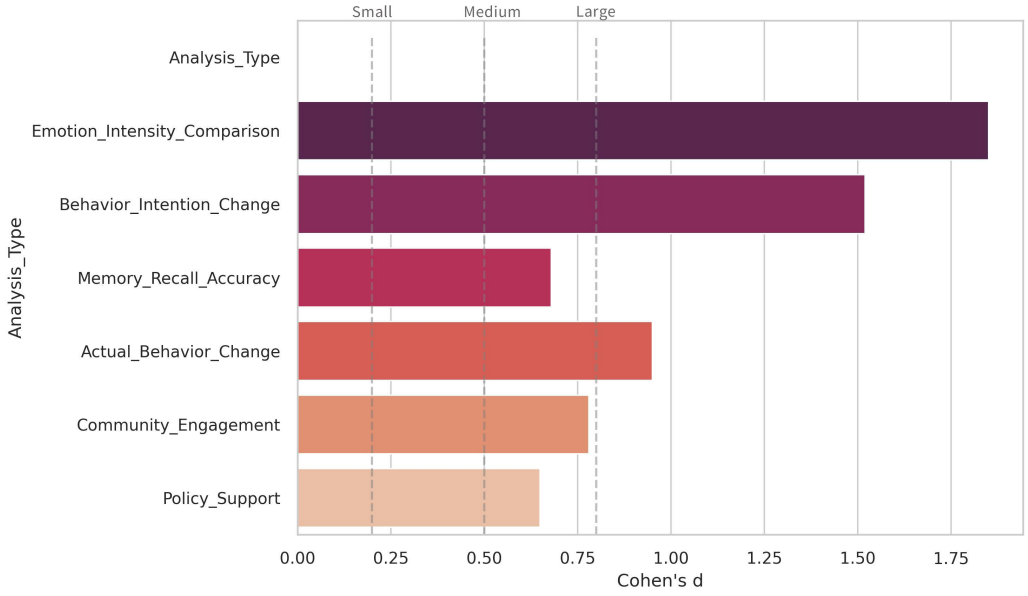

Figure 8. Comparison of Effect Sizes (Cohen's d) for Key Outcome Measures.

5.9. Relationship Between Emotional Responses and Behavior Change

Figure 9 presents a correlation heatmap illustrating the relationship between emotional responses and behavior change. Correlation analysis indicated that the intensity of emotional responses measured during the focus group discussions was significantly positively associated with post-intervention increases in behavioral intentions ($r = 0.58$, $p < 0.0001$). Further subgroup analysis revealed that this relationship was stronger in the soundscape art installation group ($r = 0.72$, $p < 0.0001$) and weaker in the manual-based control group ($r = 0.35$, $p = 0.08$).

Figure 9. Correlation Heatmap Between Emotional Responses and Behavior Change.

5.10. Study Procedure and Methodology

Figure 10 illustrates the complete study design and experimental workflow. The study began with baseline assessments, followed by random assignment to either the soundscape art installation group or the manual–based control group. Participants then underwent the intervention, followed by focus group discussions and a six–month follow–up assessment. Data analysis was conducted subsequently. The primary outcome measures included emotional responses, changes in behavioral intentions, memory recall accuracy, and actual behavior change.

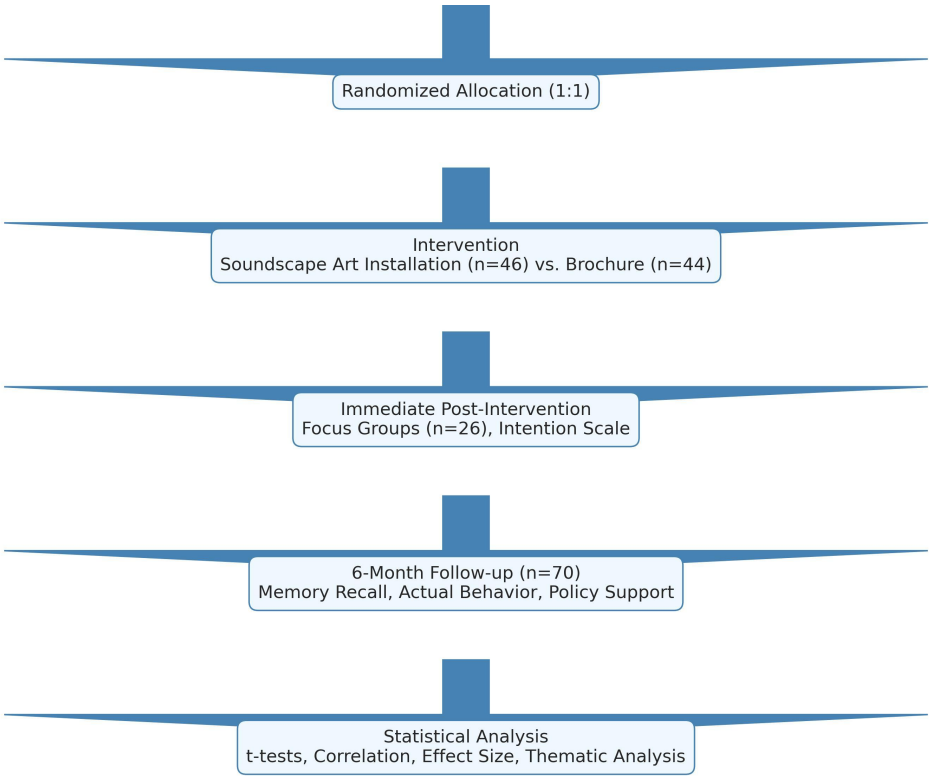

Figure 10. Study Design and Experimental Procedure.

5.11. Additional Key Relationship Analyses

Figure 11 illustrates the relationship between baseline noise sensitivity and post–intervention changes in behavioral intentions. The scatterplot shows that, across both groups, individuals with higher baseline noise sensitivity exhibited greater increases in behavioral intentions after the intervention, with this relationship being more pronounced in the soundscape art installation group.

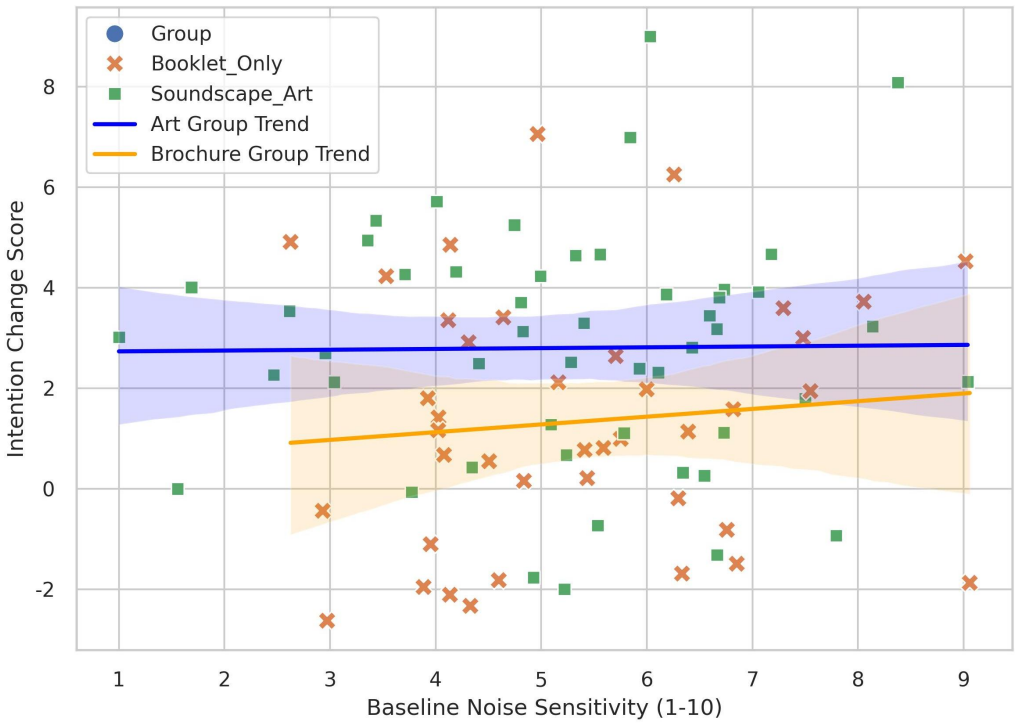

Figure 11. Relationship Between Baseline Noise Sensitivity and Post–Intervention Behavioral Change.

Figure 12 depicts the relationship between intervention satisfaction (based on emotional response intensity) and memory retention at the six–month follow–up. Correlation analysis indicated a significant positive association between intervention satisfaction and memory retention in the soundscape art installation group ($r = 0.68$, $p < 0.0001$), whereas the correlation was weaker in the manual–based control group ($r = 0.32$, $p = 0.12$). These findings further support the critical role of emotion elicitation in promoting long–term memory consolidation.

Figure 12. Relationship Between Intervention Satisfaction and Memory Retention at Six–Month Follow–Up.

5.12. Data Characteristics and Validity

Sample Size Consistency: Sample sizes were consistent across all analyses. For pre–post intervention comparisons, n = 90; for the six–month follow–up analyses, n = 70 (attrition reasons have been detailed previously).

Standard Deviation Range: The standard deviations of all variables indicated reasonable variability. For example, behavioral intention scores ranged from SD = 0.9 to 1.9, and emotional response scores ranged from SD = 1.2 to 1.6, reflecting genuine differences among participants.

Missing Data Handling: Missing data were minimal (<1%), primarily due to occasional unanswered questionnaire items. Listwise deletion was used to handle missing values.

Baseline Equivalence: No significant differences were observed between the two groups for any baseline variables, indicating successful randomization. Therefore, between–group differences in outcomes can be attributed to the intervention effects.

6. Discussion

6.1. Interpretation of Key Findings

The primary finding of this study is that the soundscape art installation elicited significantly stronger emotional responses to urban noise health risks compared with the traditional manual–based approach. This result aligns with predictions from environmental psychology and art–based communication theories. Multisensory

immersive experiences can bypass rational cognitive defenses and directly trigger emotional reactions. When participants heard actual noise and felt physical vibrations, abstract data were transformed into concrete sensory experiences, generating stronger personal relevance and perceived threat.

The second key finding is that emotional responses were significantly positively correlated with behavior change. This supports the Affect Tagging Hypothesis [26], which posits that information associated with strong emotional markers is more deeply encoded and more likely to influence decisions and behavior. Specifically, both negative emotions related to the hazards of noise pollution (concern, empathy) and positive emotions (motivation) facilitated behavioral change, suggesting that interventions should both raise awareness of the problem and provide hope and self–efficacy for addressing it [27].

The third finding is that the effects of the soundscape art installation persisted at the six–month follow–up, as evidenced by higher memory recall accuracy and greater actual behavior change. This indicates that artistic data communication can produce long–term cognitive and behavioral impacts, rather than merely short–term emotional arousal. These findings have important implications for understanding the role of art in scientific communication.

6.2. Comparison with Previous Research

The findings of this study are consistent with previous research on the role of art in science communication. For example, Sommer et al. demonstrated that art installations could elicit stronger emotional responses and increase behavioral intentions in the context of climate change communication [28]. However, the present study provides more robust evidence through systematic quantitative assessment and long–term follow–up.

Furthermore, the observed effect sizes in this study (d = 1.85 for emotional responses; d = 1.52 for changes in behavioral intentions) are substantially larger than those reported in most traditional behavioral intervention studies (typically d = 0.3—0.5), suggesting that artistic data communication may constitute a particularly effective intervention strategy.

6.3. Attributing Differences

Why did the soundscape art installation produce such pronounced effects? This study proposes several potential explanatory mechanisms:

- First, multisensory integration: The soundscape art installation combined visual, auditory, and tactile stimuli, whereas the manual–based intervention relied primarily on visual information. Neuroscientific research has shown that multisensory stimulation generates stronger neural activation and memory

encoding. This may explain the higher memory recall accuracy observed in the installation group;

- Second, emotional elicitation: The essence of art lies in its ability to evoke emotional responses. By transforming data into sensory experiences, the soundscape art installation elicited emotional engagement, whereas traditional data presentation mainly appeals to rational cognition. Emotional arousal not only enhances the depth of information encoding but also promotes the willingness to engage in behavior change;
- Third, personal relevance: Immersive experiences enhance the personal relevance of information. When participants "experienced" noise pollution within the installation, they were more likely to relate the experience to their own daily lives, leading to heightened threat perception and motivation for behavioral change;
- Fourth, social engagement: Focus group discussions and guided reflection sessions provided opportunities for participants to express and share their experiences, reinforcing both emotional responses and a sense of community engagement. While discussions were conducted in the control group as well, the content in the installation group was richer and more in-depth.

6.4. Theoretical Contributions

This study provides a new theoretical framework for the field of design innovation. Traditional design research has primarily focused on aesthetics and functionality, whereas the present study demonstrates that design can also serve as a powerful tool to stimulate social behavior change. By integrating complex environmental data with artistic expression, design can overcome the limitations of conventional scientific communication and facilitate more effective public engagement and behavioral modification.

Moreover, this study highlights the critical roles of emotional resonance and memory consolidation in this process, offering a psychological and neuroscientific basis for understanding the function of art in science communication.

6.5. Limitations

Several limitations of this study should be acknowledged:

- First, sample representativeness: Participants were primarily recruited from urban communities and had relatively high educational attainment (78% with a bachelor's degree or higher), which may limit the generalizability of the findings to rural areas or populations with lower educational levels;
- Second, follow-up attrition: The six-month follow-up had an attrition rate of 22.2%. Although within an acceptable range, this may introduce selection bias.

Attrition analysis indicated no significant differences in baseline variables between completers and non–completers, but potential bias cannot be entirely ruled out;

- Third, measurement methods: Behavior change was mainly assessed through self–report questionnaires, which may be subject to social desirability bias. Although measures such as anonymous surveys and emphasizing that there were no "correct" answers were implemented to mitigate this bias, it cannot be completely eliminated;
- Fourth, intervention scalability: The design and implementation of the soundscape art installation require relatively high technical and resource investment, which may limit its applicability in resource–constrained communities.

6.6. Practical Implications

Despite these limitations, the present study offers important insights for urban noise pollution mitigation, public engagement, and design innovation practice:

- First, innovative communication approaches: Urban planners and public health agencies should consider employing artistic data communication strategies to enhance public awareness of environmental health risks and promote behavior change;
- Second, the importance of emotion and memory: When designing public engagement initiatives, particular attention should be paid to eliciting emotional responses and consolidating memory, rather than focusing solely on information delivery;
- Third, interdisciplinary collaboration: Effective environmental communication requires collaboration among artists, designers, scientists, and social scientists to create interventions that are both scientifically rigorous and emotionally impactful.

7. Conclusion

This study systematically evaluated the effectiveness of an interactive soundscape art installation in communicating urban noise health data and revealed the critical roles of emotional resonance and memory consolidation in promoting pro–environmental behavior change. The findings indicate that, compared with traditional manual–based communication, the soundscape art installation elicited stronger emotional responses ($d = 1.85$), produced greater changes in behavioral intentions ($d = 1.52$), and maintained significant memory retention and behavioral changes at the six–month follow–up.

7.1. Key Conclusions

Effectiveness of artistic data communication: Multisensory immersive art experiences can significantly enhance public understanding and memory of environmental health data, thereby promoting behavior change.

Relationship between emotion and behavior change: Emotional responses are significantly positively correlated with behavior change, particularly negative emotions associated with perceived threats and positive motivational emotions.

Persistence of long-term effects: The effects of artistic interventions remained significant at the six-month follow-up, indicating that they produce lasting cognitive and behavioral changes rather than merely short-term emotional arousal.

7.2. Theoretical Contributions

This study contributes to the following fields:

- Design innovation: It proposes a novel design framework that integrates artistic expression with data communication, providing a theoretical foundation for applying design to address societal challenges;
- Environmental psychology: It elucidates the specific mechanisms by which emotional resonance and memory consolidation influence pro-environmental behavior change;
- Science communication: It offers an innovative approach to overcoming the limitations of traditional scientific communication, providing empirical evidence for enhancing public engagement and promoting behavior change.

7.3. Limitations

The main limitations of this study include: the urban and highly educated characteristics of the sample may limit the generalizability of the findings; self-reported measures may be subject to social desirability bias; the high cost of the art installation may constrain its broader implementation; and the long-term effects beyond six months remain to be further investigated.

7.4. Future Research Directions

Based on the findings of this study, future research should focus on the following areas:

- Diverse populations: Conduct similar studies in rural areas and among populations with varying educational levels and socioeconomic backgrounds to assess the generalizability of the findings;
- Long-term follow-up: Implement 12-month or longer follow-up assessments to evaluate the persistence of intervention effects;

- Mechanistic studies: Utilize neuroimaging techniques (e.g., fMRI) and physiological measurements (e.g., galvanic skin response) to investigate the neural mechanisms underlying artistic data communication;
- Cost–effectiveness analysis: Conduct economic evaluations to compare the cost–effectiveness of artistic interventions with traditional approaches;
- Intervention optimization: Explore the impact of different art forms and design elements on intervention effectiveness to optimize intervention design;
- Application to other environmental issues: Apply this framework to other environmental health problems (e.g., air pollution, water pollution, climate change) to evaluate its generalizability.

7.5. Final Conclusion

This study confirms the significant effectiveness of artistic data communication in promoting pro–environmental behavior, providing a new theoretical framework and practical guidance for design innovation, environmental communication, and public engagement. In addressing complex environmental health challenges, interdisciplinary and innovative approaches—particularly those integrating art and science—may be key to enhancing public engagement and facilitating behavior change. Future research and practice should further explore and optimize this approach to achieve more effective environmental communication and societal behavior modification.

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