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ORIGINAL ARTICLE

A Participatory Neuroacoustic Data Infrastructure for Experimental Health Research

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ABSTRACT

Co-creation is widely invoked in digital health and creative technologies, yet it is rarely operationalised as a rigorous experimental research infrastructure. This paper introduces a transferable framework for structuring co-created health data systems using creative neuroacoustic platforms as situated experimental apparatuses. We present a dual-stream methodology that combines longitudinal participatory platform data with an exploratory controlled experimental study. This approach enables the generation of context-rich datasets while explicitly focusing on infrastructure feasibility, governance design, and experimental reproducibility rather than clinical efficacy. The results demonstrate how such platforms can function as experimental data infrastructures by supporting longitudinal engagement, revealing culturally situated usage and outcome patterns, and operationalising governance mechanisms for consent, provenance, and attribution. The framework positions creative platforms as experimental data commons bridging scientific research, creative practice, and industry contexts, while supporting hypothesis generation for future longitudinal health research without over-claiming therapeutic outcomes. This work contributes a transdisciplinary model for experimental innovation that integrates creative technologies, participatory governance, and health research infrastructure design. Ultimately, this framework repositions participatory creative platforms not as passive consumer applications, but as a new class of experimental data infrastructure for health research.

Keywords: Co-creation; neuroacoustics; experimental innovation; data commons; participatory infrastructure; digital health; creative research systems.

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INTRODUCTION

Co-creation is increasingly mobilised across science, industry, and culture as a strategy for addressing complex societal challenges that exceed disciplinary and institutional boundaries (Prahalad & Ramaswamy, 2004). In digital health and creative technologies, participatory platforms have enabled new forms of longitudinal engagement, experiential intervention, and real-world data generation beyond traditional clinical and laboratory settings.

Sound-based and neuroacoustic interventions exemplify this convergence, as immersive audio systems and spatial sound infrastructures shape perceptual and affective experience through distributed neural mechanisms, while simultaneously functioning as creative and technological platforms (Zatorre & Salimpoor, 2013). However, despite their widespread deployment in practice, such platforms are rarely designed or evaluated as scientific research infrastructures.

Most participatory creative platforms prioritise user experience and engagement but lack the methodological scaffolding required for experimentation-driven research, including standardised stimulus design, explicit governance mechanisms, and reproducibility frameworks. As a result, their potential contribution to interdisciplinary research and longitudinal health knowledge generation remains underdeveloped.

This gap is particularly relevant in the context of health research, where there is a growing need for longitudinal and context-rich datasets capable of capturing variability across individuals, cultures, and environments. In parallel, creative technologies and spatial sound systems are increasingly deployed as experimental environments bridging academic research, artistic practice, industry, and civil society. At the same time, artificial-intelligence-driven personalisation systems require ethically governed datasets with explicit consent, provenance, and attribution structures to avoid bias and extractive data practices.

This paper addresses these gaps by introducing a transferable framework for co-created neuroacoustic data infrastructures, illustrated through an experimental participatory platform case study. The framework conceptualises participatory neuroacoustic platforms as socio-technical research infrastructures in which specific roles—platform participants, sound designers, and research facilitators—co-produce experimental artefacts

and longitudinal data under defined methodological and governance constraints.

The research is guided by the following questions:

- How can co-creation be operationalised as a participatory data infrastructure for neuroacoustic pain and wellbeing research?
- What governance, consent, and metadata structures are required to ensure ethical, reproducible, and culturally contextualised participatory datasets?
- How can creative digital platforms function as experimental research infrastructures for longitudinal health research and responsible artificial-intelligence development without over-claiming clinical efficacy?

By addressing these questions, this work positions participatory neuroacoustic platforms as experimental data infrastructures that redistribute agency across clearly defined roles within the research process. This framing conceptualises such platforms as experimental data commons aligned with Ostrom's governance of common-pool resources (Ostrom, 1990), open innovation, and Industry Commons paradigms, contributing to interdisciplinary experimental innovation across health research, creative industries, and digital research infrastructures.

Structurally, the proposed framework conceptualises participatory neuroacoustic platforms through four interrelated infrastructural layers: (1) an experimental artefact layer (standardised neuroacoustic stimulus design), (2) a co-creation layer (participatory digital platform engagement), (3) a governance layer (consent, provenance, and attribution protocols), and (4) a knowledge infrastructure layer (longitudinal data generation and iterative feedback).

METHODS AND DATA

This study adopts an experimental, case-based methodology that conceptualises a participatory neuroacoustic platform as a socio-technical research infrastructure for co-created data generation. The platform delivers structured neuroacoustic soundscapes and captures user-generated interaction data, including self-reported pain and stress measures, engagement metrics, and contextual metadata. Rather than evaluating clinical efficacy, the methodological focus is on infrastructure feasibility, governance design, and participatory data production for experimentation-driven research.

Neuroacoustic sound-based interventions and non-pharmacological acoustic stimulation have previously been explored in health and wellbeing contexts, including pain perception and music-induced analgesia, providing a precedent for the use of auditory stimulation as a modulatory experimental variable (Garza-Villarreal et al., 2017; Sihvonen et al., 2022; Arnold et al., 2024; Albesher et al., 2025; Song et al., 2026). Building on this lineage, the present paper focuses on how such interventions can be operationalised within participatory digital infrastructures.

Data sources

Two complementary data streams were employed to investigate the feasibility and implications of co-created neuroacoustic data infrastructures.

Stream 1: Participatory platform data.

Longitudinal platform-generated interaction data were collected from a large-scale user cohort (N = 10,322 unique users). Data included sound usage patterns, self-reported wellbeing measures (Visual Analogue Scale for pain and stress), mood annotations, engagement metrics, and demographic and contextual segmentation variables. These datasets represent real-world, heterogeneous, and culturally contextualised participatory data generated through ongoing platform use and co-creation processes.

This work intentionally adopts a transdisciplinary vocabulary bridging experimental health research, creative practice, and participatory data governance, reflecting the hybrid nature of the infrastructures under study.

Stream 2: Exploratory controlled experimental study.

An exploratory pilot study was conducted in a physiotherapy setting with 40 participants to compare structured neuroacoustic soundscapes with non-structured music control conditions. Outcomes included Visual Analogue Scale (VAS) measures for pain and stress. This stream provided controlled comparative data to inform stimulus calibration, methodological design choices, and the translation of controlled experimental conditions into real-world participatory deployment, rather than to assess clinical efficacy.

Neuroacoustic stimulus design

Neuroacoustic stimuli were designed using standardised sound design parameters specifying entrainment frequency ranges, tempo constraints, compositional rules, and spatialisation characteristics. These parameters were developed through iterative collaboration between platform designers and sound artists, positioning creative practitioners as co-researchers in the stimulus design process. Sound artefacts were treated as experimental artefacts with traceable metadata, versioning, and documented design constraints to support reproducibility across experimental and participatory contexts.

Data collection and governance mechanisms

Data were collected through in-platform self-reporting instruments informed by clinical assessment practices, platform telemetry logs, and structured sound

deployment protocols. Ethical governance and informed consent were structured according to the operational contexts of each data stream. For Stream 1 (Participatory Platform Cohort, N=10,322), digital informed consent and data processing authorizations were embedded within the platform's Terms of Service and Privacy Policy, explicitly agreed to by users upon account creation and session initiation. For Stream 2 (Exploratory Controlled Pilot, n=40), non-invasive sound exposure was integrated into standard physical therapy sessions under institutional clinical intake guidelines, with verbal informed consent obtained prior to exposure in accordance with institutional research ethics principles and the Declaration of Helsinki. All data across both streams were fully anonymized at collection and aggregated to ensure participant privacy and compliance with institutional data governance standards.

Formal institutional review board (IRB) approval was not required, as the participatory platform data consisted of retrospective, fully anonymized and aggregated user interaction telemetry processed under platform Terms of Service, and the pilot study involved non-invasive sound exposure integrated into standard private physiotherapy practice without altering clinical pathways.

Analytical approach

Analysis focused on descriptive statistics, comparative outcome measures, and infrastructural feasibility assessment rather than clinical efficacy claims. The objective was to evaluate the participatory platform as an experimental innovation infrastructure, identify governance requirements, and examine socio-cultural confounds inherent to participatory neuroacoustic datasets.

The exploratory pilot study informed the subsequent design and scaling of the participatory platform as a longitudinal experimental infrastructure, enabling translation from controlled experimental conditions to real-world co-creation environments.

RESULTS

Results are structured around two experimental streams: (1) an exploratory controlled neuroacoustic pilot study and (2) longitudinal participatory platform co-creation data. The analysis focuses on infrastructure feasibility, socio-cultural confounds, and governance artefacts rather than clinical efficacy.

Controlled neuroacoustic pilot outcomes

An exploratory, open-label physiotherapy pilot study (n = 40) was conducted in a private physical therapy practice (FisioJulia) involving adult outpatients diagnosed with musculoskeletal conditions (including cervicalgia, low back pain, and herniated discs). Participants were sequentially allocated to either a structured neuroacoustic soundscape condition (n = 20; listening via speakers during standard physiotherapy) or a non-structured music control condition (n = 20; listening to conventional music). Self-reported pain and stress were recorded before and after each session using a standard 0–10 Visual Analog Scale (VAS). The pilot study provided descriptive, open-label observational data to calibrate stimulus parameters rather than to infer comparative clinical efficacy. Self-reported pain and stress were recorded using a standard 0–10 Visual Analog Scale (VAS). Within the structured soundscape group (n=20), descriptive mean VAS reductions of 3.1 points for pain and 2.7 points for stress were observed, compared to 1.3 and 0.4 points respectively in the non-structured music control group (n=20). These exploratory observations served primarily to evaluate feasibility and inform stimulus refinement for deployment within the participatory platform.

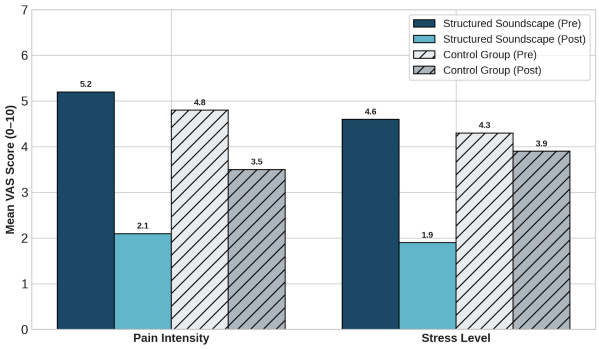
These findings demonstrate the feasibility of deploying structured neuroacoustic stimuli as reproducible experimental artefacts within controlled applied settings. Auditory stimuli were designed through a centralized sound creation framework that synthesized existing neuroacoustic literature, expert advisory feedback, acoustic and technical feasibility, and preliminary user feedback. Design parameters specified theoretical oscillatory targets within delta (2–4 Hz) and alpha (~10 Hz) ranges as intended compositional targets—aligned with brainwave entrainment and auditory stimulation frameworks for pain modulation (Gkolias et al., 2020; Bartel & Mosabbir, 2021; Arnold et al., 2024; Song et al., 2026)—alongside tempo constraints aligned with relaxed heart rate rhythms (~60-75 BPM) and compositional rules structured to avoid cognitive fatigue and overstimulation. Neuroacoustic effects were implemented through rhythmic amplitude modulation and sustained harmonic structures rather than discrete musical events. Auditory stimuli were delivered via standard playback (headphones or speakers, depending on the experimental setting).

Consistent with prior vibroacoustic research, the pilot study functioned as a calibration layer for stimulus design parameters rather than an assessment of clinical efficacy (Bartel & Mosabbir, 2021). Insights from this stream directly informed the subsequent deployment of structured neuroacoustic artefacts within the participatory platform infrastructure.

Table 1. Comparative outcomes and descriptive metrics of the controlled pilot study in a private physiotherapy setting (FisioJulia, n = 40) using Visual Analog Scale (VAS 0–10) measures.

Metric / Parameter	Structured Soundscape Group (n = 20)	Control Group (n = 20)
Applied Setting & Delivery	Outpatient Physiotherapy / Speakers	Outpatient Physiotherapy / Speakers
Baseline Mean VAS Pain (0–10)	5.2 (SD = 1.9)	4.8 (SD = 2.3)
Post-Session Mean VAS Pain	2.1 (SD = 1.9)	3.5 (SD = 1.6)
Mean VAS Pain Reduction	3.1 (SD = 1.9)	1.3 (SD = 1.4)
Baseline Mean VAS Stress (0–10)	4.6 (SD = 2.3)	4.3 (SD = 2.4)
Post-Session Mean VAS Stress	1.9 (SD = 1.4)	3.9 (SD = 1.4)
Mean VAS Stress Reduction	2.7 (SD = 1.0)	0.4 (SD = 0.8)

Graph 1. Controlled Pilot Study Outcomes: Pre-. vs Post-Interventions (n = 40).



Platform-based co-creation data patterns and demographic confounds

Longitudinal participatory platform data collected from 10,322 unique users revealed heterogeneous engagement patterns and context-dependent outcome signals. Users across different geographic and cultural regions exhibited distinct listening behaviours, session frequencies, and self-reported outcome trajectories. Preliminary comparative patterns indicated variation in engagement intensity and VAS reduction signals across regions, including Southeast Asia and Latin America.

These findings highlight the role of cultural, linguistic, and contextual variables as confounds in participatory neuroacoustic datasets and demonstrate the necessity of structured metadata schemas capable of capturing demographic, contextual, and cultural variables. The results indicate that participatory neuroacoustic datasets are culturally situated, and that experimental infrastructures must explicitly encode contextual metadata to mitigate epistemic bias in AI-driven health research.

Table 2 Platform engagement metrics derived from participatory co-creation data.

Platform Metric	Platform Cohort
Unique users	10,322
Average listening duration	21.7 minutes
Maximum sessions per user	524 sessions

Governance artefacts and experimental infrastructure design

The study operationalised a governance artefact comprising structured consent protocols, data provenance tracking, attribution mechanisms, and standardised neuroacoustic stimulus design parameters (frequency bands, tempo constraints, and compositional rules) (Martín-Saavedra et al., 2018). This artefact enabled reproducible stimulus deployment across both controlled and participatory environments and provided a framework for ethical participatory data governance.

The governance artefact functions as an experimental infrastructure layer supporting reproducibility, co-creation attribution, and ethical data stewardship within creative digital health platforms.

Table 3. Neuroacoustic stimulus design parameters.

Design Parameters	Test Group / Platform
Target entrainment frequencies	2–4 Hz (delta), ~10 Hz (alpha)
Tempo constraints	60–75 BPM

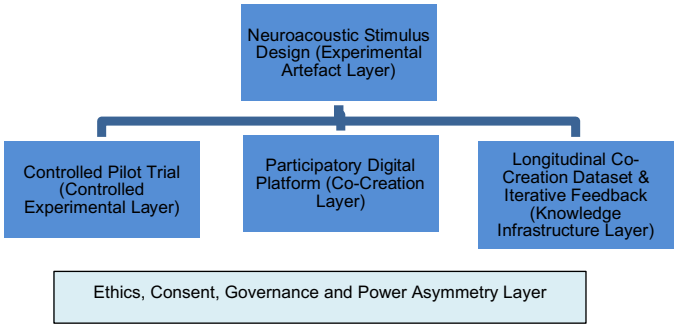


Fig. 1. Experimental pipeline illustrating the transition from controlled neuroacoustic stimulus calibration to participatory digital platform co-creation and longitudinal dataset generation, with embedded governance and consent layers.

DISCUSSION AND CONCLUSIONS

This study demonstrates the feasibility of positioning participatory neuroacoustic platforms as experimental co-creation infrastructures rather than solely therapeutic or artistic tools. By integrating controlled neuroacoustic stimulus design with longitudinal participatory datasets, the proposed framework shows how creative digital platforms can function as socio-technical research infrastructures for experimentation-driven innovation.

Within this framework, creative technologies are conceptualised as experimental infrastructures analogous to large-scale scientific instruments, in which participatory users and creative practitioners contribute to data generation and experimental operation. Such infrastructures extend experimental research beyond laboratory settings into everyday cultural and digital environments, aligning with emerging experimental commons and citizen science paradigms.

The results indicate that co-created neuroacoustic platforms can operate as experimental data commons by redistributing agency across clearly defined roles, including platform participants, sound designers, and research facilitators. The participatory infrastructure enabled longitudinal data generation in real-world contexts while embedding governance artefacts for consent, provenance, attribution, and reproducibility. In doing so, the study contributes to Industry Commons and open innovation paradigms by demonstrating how creative technologies can be structured as experimental infrastructures rather than extractive consumer platforms.

A key implication concerns the role of participatory longitudinal data in health research. While the present study does not claim clinical efficacy, the findings suggest that structured co-creation platforms can support early pattern detection, cohort stratification, and hypothesis generation in heterogeneous and underrepresented populations. By embedding contextual metadata, demographic segmentation, and continuous self-reported measures, such infrastructures may reduce time-to-signal in exploratory research pipelines and inform future research design without substituting for clinical diagnosis or validation.

The study also highlights the role of artists and creative practitioners as co-researchers within experimental infrastructures. Through structured sound design parameters, composers and sound designers contribute to stimulus calibration, transforming creative variables such as frequency range, tempo, spatialisation, and compositional structure into experimental parameters. This reframes creative labour as an epistemic contribution and introduces models of functional composition grounded in research-oriented sound practices. These dynamics raise broader questions regarding attribution, value creation, and governance within participatory experimental systems.

Several limitations must be acknowledged. The controlled pilot study was exploratory and involved a limited sample size, while platform-based data relied on self-reported measures without clinical validation. Cultural and demographic segmentation was observational rather than experimentally controlled, limiting causal inference. In addition, participatory platform datasets are subject to selection bias, technological mediation effects, and governance challenges inherent to real-world co-creation systems. These constraints reinforce the positioning of the present work as a methodological and infrastructural contribution rather than a clinical efficacy study.

Future research directions include controlled longitudinal studies integrating participatory platforms with clinical data collection, adaptive neuroacoustic systems incorporating artificial intelligence, and comparative investigations of spatial audio environments (Sharma, 2025). Beyond core compositional variables, future research should explore how spatial acoustic rendering, multi-channel omnidirectional sound fields, and spatialization software—such as 4DSOUND, L-Acoustics, or Dolby Atmos — influence perceptual spatialization, psychoacoustic pain modulation, and mastering workflows for health-oriented data collection. The experimental pipeline presented here could be deployed in interdisciplinary laboratory settings, living labs, and public innovation contexts, including student-led experimental innovation programmes, to examine co-creation dynamics, governance models, and reproducibility across participatory research infrastructures.

In conclusion, this work positions co-created neuroacoustic platforms as experimental infrastructures integrating creative practice, participatory governance, and longitudinal data generation. By framing co-creation as an infrastructural and methodological construct rather than solely a design approach, the study contributes a transdisciplinary model for experimental innovation across health research, creative technologies, and participatory data governance.

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CONFLICT OF INTEREST

Laura Sigrid J. Clarke is the founder of Moonai SL, the platform used for data collection in this study. Lee Bartel and Thomas Burgué have served as scientific and

creative advisors to the project, contributing to the initial design framework, sound parameters, and stimulus calibration based on research, exploratory testing, and user feedback. While the platform data was generated within this ecosystem, the authors declare that the conceptual framework, infrastructural analysis, and methodology presented in this manuscript were developed independently for experimental research purposes.

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This research received no direct academic grant funding. Platform infrastructure development and data collection were supported through internal operational resources of Moonai SL, partially leveraged by public innovation funding from ENISA (Empresa Nacional de Innovación, S.A., Spain) and private venture financing.

AUTHOR CONTRIBUTIONS

Laura Sigrid J. Clarke: Conceptualization, Funding Acquisition, Methodology, Platform Infrastructure Design, Audio-Visual Technology Integration, Data Collection, Formal Analysis, Writing – Original Draft, Project Administration.

Lee Bartel: Scientific Advisory, Conceptual & Methodological Review, Stimulus Calibration Supervision, Writing – Review & Editing.

Thomas Burgué: Sound Design Framework, Artistic Composition & Audio Parameterization, Spatial Audio Calibration, Writing – Review & Editing.

AI-ASSISTED TECHNOLOGY STATEMENT

AI-based language tools were used to assist with copyediting and proofreading of the manuscript text. All scientific content, data analysis, and interpretation are the authors' own.

SUPPLEMENTARY MATERIALS

Supplementary materials accompanying this manuscript provide additional methodological documentation, aggregated datasets, and experimental artefacts supporting the research. These materials complement the core findings reported in the main text and are intended to enhance transparency, reproducibility, and educational reuse. The supplementary materials are structured to support replication in interdisciplinary laboratories, student experimental innovation programmes, and participatory research settings.

Supplementary Material S1: Aggregated Longitudinal User Interaction Dataset

An anonymised summary of longitudinal user interaction metrics collected through the participatory platform, including engagement frequency, session duration, and self-reported pain and stress scores.

Available upon reasonable request.

Supplementary Material S2: Neuroacoustic Sound Design Framework

Technical documentation detailing compositional constraints, entrainment frequency ranges, tempo parameters, and spatialisation principles used to standardise experimental neuroacoustic stimuli.

Available upon reasonable request.

Supplementary Material S3: Participatory Data Governance and Co-Creation Protocol

Methodological documentation describing consent procedures, participatory research workflows, and governance mechanisms supporting ethical co-creation in health-related digital platforms.

Available upon reasonable request.

Supplementary Material S4: Descriptive Statistics and Demographic Segmentation Tables

Additional tables presenting demographic distributions, geographic segmentation, and comparative descriptive outcomes across cultural contexts.

Available upon reasonable request.

Supplementary Material S5: Controlled Neuroacoustic Sound Exposure Pilot Results

Summary documentation of preliminary controlled experiments using structured neuroacoustic sound stimuli conducted in non-platform experimental settings, including subjective outcome measures. *Available upon reasonable request.*

DATA AVAILABILITY STATEMENT

Due to commercial confidentiality and participant privacy agreements under platform Terms of Service, raw individual interaction telemetry is protected. However, fully anonymised and aggregated data summaries (Supplementary Materials S1–S5) and framework governance protocols are archived and publicly accessible via Zenodo (https://doi.org/10.5281/zenodo.21813397) and within the Moonai research repository, available for scientific and educational reuse from the corresponding author upon reasonable request.

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