DESIGN ENGINEERING RESEARCH BOOKLET

Poster Symposium 2025

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CONTENT

Bernardo, Francisco ---------- 4
Impedance Synthesis for Hybrid Analog-Digital Audio Effects
Canghizer, Diana ---------- 5
Design Methods for Enacting Complex and Stigmatised Women ' s Health Narratives in Fem Tech Design Process
Cho, Minseo ---------- 6
Translating Skateholder expectations into Architecture of Conversational Systems through Flowcharts
Fang, Gaoyun ---------- 7
Understanding Multimodal Fusion through Cross-Modal Interaction
Koczias, Cece ---------- 8
Climate Risk Identification in Medium-sized Firms in the UK
Kuhn, June ---------- 9
Transsomatic: Bodily Mutation through Autobiographical of Vocal Practice
La Magna, Nicola ---------- 10
Spatial Release From Masking and Listening Effort: Differences Between Binaural and Free-field Presentation
Liang, Shihui ---------- 11
Pathways to Net-Zero: A Systematic Review of Corporate Climate Strategy, Mechanisms and Performance
Lin, Mingnan ---------- 12
The Role of Rituals in Hybrid Work Environments: A Integrative Review
Medd-Sygrove, Bryn ---------- 13
Reconsidering Entrepreneurial Ecosystems: A Problematising Review and Way Forward
Nightingall, Georgie ---------- 14
Designing for Better Weak Tie Human Connectivity Outcomes
Pirard, Ludovic ---------- 15
Towards Accessible Individual Head-related Transfer Functions For Spatial Audio Applications
Schmidt, Adam ---------- 16
Sustained Interests: Electromagnetically Actuated Feedback Instruments
Tang, Tonghui ---------- 17
Marker Information Efficacy:Enhancing Vision-based Tactile Sensing through Deformation-aligned Marker Design
Tian, Haozhe ---------- 18
Learning Network Dismantling without Handcrafted Features

CONTENT

Webb, Jack ---------- **19**
Modelling Perceived Audio Quality in Hearing AIDS Using Pairwise Comparisons
Wickramanayake, Tosh ---------- **20**
A Continuum-Scale Model for Nickel-Rich Cathode Degradation in Lithiumion Batteries
Yang, Eddie ---------- **21**
Development of an Automated Transtibial Prosthetic Socket Design Pipeline
Zhao, Xiaoyang ---------- **22**
Behaviour Setting-Driven Extended Reality: Framework, Tool and Guidelines

Impedance Synthesis for Hybrid Analog-Digital Audio Effects

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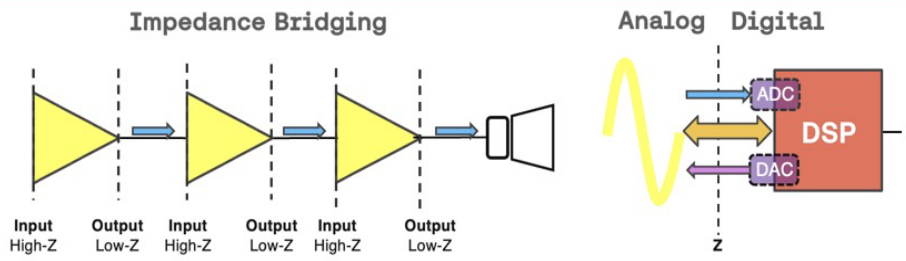
Enabling the design of hybrid systems where virtual analog simulation co-exists flexibly with literal analog systems by restoring reciprocity across the physical-digital boundaries

Abstract

An approach to hybrid analog-digital audio processing using synthetic impedance: digitally simulated circuit elements integrated into an analog circuit. This approach combines the physicality and classic character of analog audio circuits alongside the precision and flexibility of digital signal processing (DSP). Our impedance synthesis system consists of a voltage-controlled current source and a microcontroller-based DSP system.

Rationale

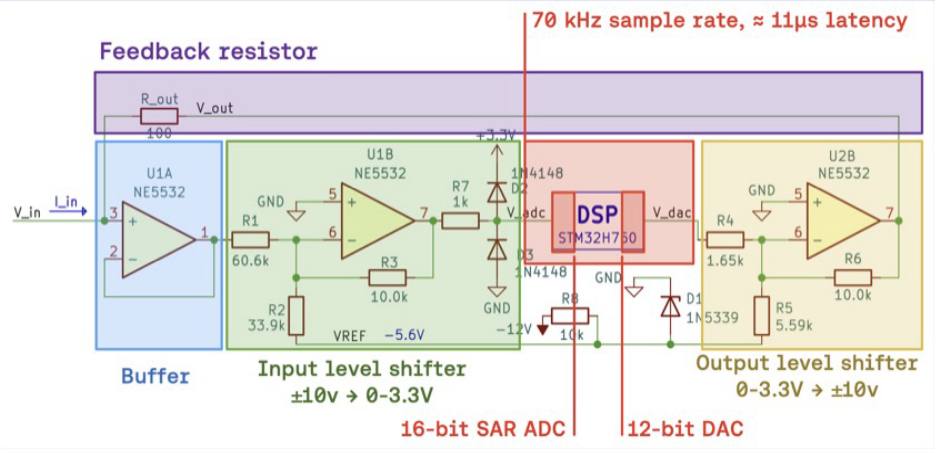
Physical systems, whether mechanical, acoustic, or electrical exhibit reciprocity, a bidirectional exchange of energy between coupled elements. However, in modern audio systems, this is deliberately mitigated through impedance bridging to maximise modularity and convenience for engineering and design. This enforces a unidirectional flow – from the output of one module to the input of the next, preventing interaction between elements within a system. With hybrid analog-digital processing, it is up to the designer to draw the boundary of where unidirectionality is enforced.



This is also relevant to Virtual Analog systems design, where impedance boundaries delimit the digital simulation domain. There is an opportunity to design systems where digital simulation co-exists flexibly with literal analog systems, without such well defined input/output boundaries

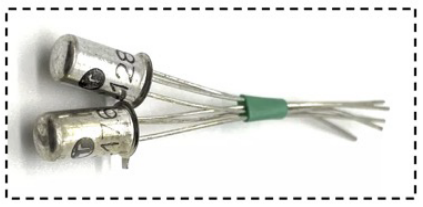
System Design

Our impedance synthesis system consists of a voltage-controlled current source and a microcontroller-based DSP system.

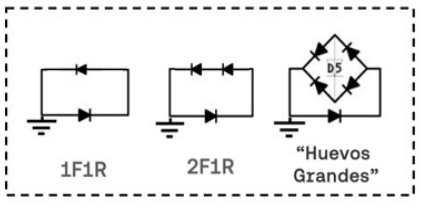


Applications

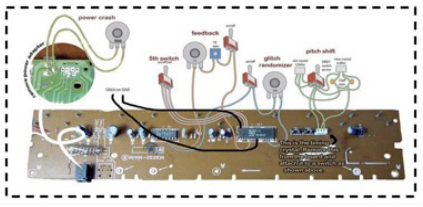
- Replacing obsolete components



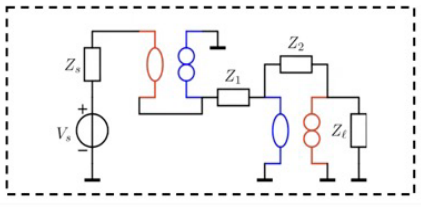
- Physicality with on-the-fly configurability



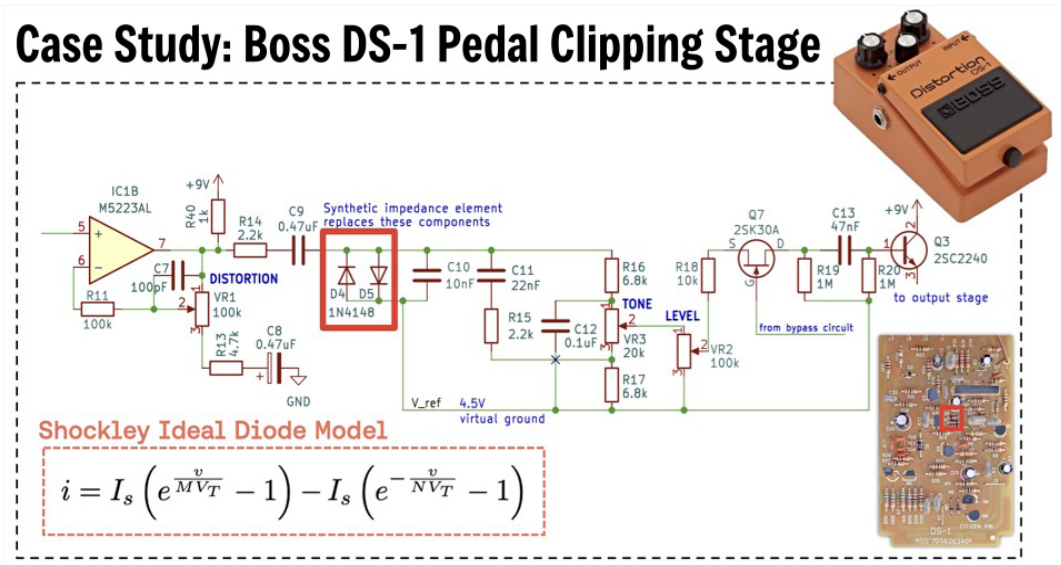
- Circuit bending



- Integrating theoretical/ideal components

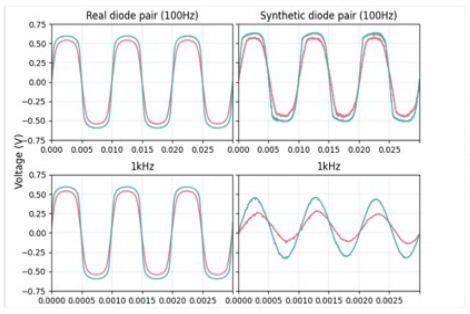


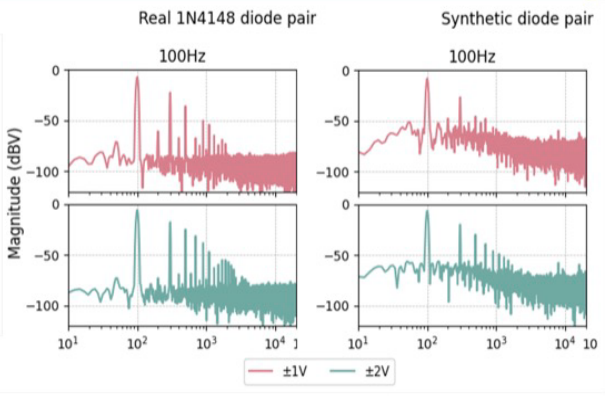
Case Study: Boss DS-1 Pedal Clipping Stage



Results

We conducted analyses in the time and frequency domains, and compared between the synthetic diodes and the real diodes behaviours, both in isolation and within the DS-1 circuit. The waveforms show similar performance, with the diodes clipping the signal at approximately ±0.55V. The phase shift due to the system latency causes the lower level at 1kHz. Frequency analysis showed similar spectral content, with odd harmonics due to the symmetrical clipping of diodes.





Main Takeaways

- Bidirectional coupling restored across audio circuits physical-digital boundaries
- Challenging calibration of the synthetic impedance component (feedback loop sensitivity requires high precision components)
- Convergence between physical (1N4148 diodes) and synthetic behaviour
- Latency affects stability at high frequencies leading to reduced system bandwidth

Future Work

- Higher sampling rates, lower latency
- Faster ADC, higher resolution DAC
- Differential inputs (floating)
- Wave Digital Filters for synthesis of more complex network impedance
- Apply to new forms of control and modulation

Bio

Dr Francisco Bernardo is a Research Associate in Digital Musical Instrument Design at the Augmented Instruments Lab within the Dyson School of Design Engineering, Imperial College London. His research is centered on advancing digital musical instrument design with critical design, hybrid digital-analog circuits, virtual analog modeling, and embedded systems.

References

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QR Code

Design Methods for Enacting Complex and Stigmatised Women's Health Narratives in FemTech Design Process

> "Designing women's health tech requires navigating complex lived realities. This project is developing gender-responsive and context-sensitive methods aimed at surfacing emotional and embodied types of knowledge of stigmatised health narratives."

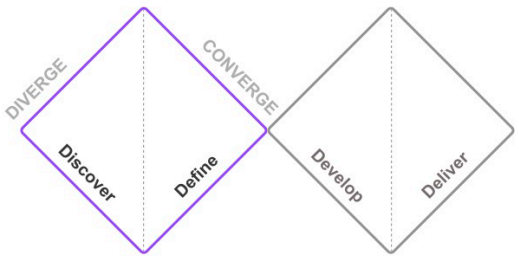
Diana Canghizer
Dr Céline Mougenot, Dr Talya Porat

Abstract

FemTech has the potential to transform women's health, yet many digital health solutions fail to fully engage with the complex socio-cultural realities of women's health lived experiences. They often rely on reductive and normative assumptions, and current practices overlook narratives on sensitive and stigmatised topics. This project explores how gender-responsive design methods can better engage with stigmatised health experiences, supporting the creation of socio-cultural relevant FemTech innovations. It develops novel methods and tools to elicit, surface, and translate stigmatised health experiences into informed design decisions. Ultimately, helping health innovators to design solutions that are not only technologically effective but also socio-culturally relevant and responsive to diverse realities of women's health.

Positionality and Research Problem

Fig 1. Herlo B. - Example of participatory design session



Facilitation, elicitation, collection, collective imagining and co-designing

Intervention focused on 'Discovery' and 'Define' impacting all phases of the Double Diamond

Digital health technologies for women's health, known as ***FemTech***, have rapidly grown, spanning mobile apps, wearables, and service systems (Chaléat and Baud, 2023; Kronemyer, 2018). Even so, the current state of designing digital health poses significant **challenges in understanding context and users** (Pagliari, 2007; Cummings and Teal, 2023). This is even more challenging when it comes to designing digital solutions for women's healthcare considering **intimate and stigmatised bodily experiences.** (Søndergaard, 2020). Recent examples highlight platforms lacking appropriate design to support sexual health (Rushe, 2011; Wilson et al., 2017) or promoting menstrual stigma (Homewood, 2018). While the importance of lived experience in designing health technologies is recognised, there is limited clarity on the specific design practices needed to elicit stigmatised narratives and specific types of knowledge in women's health (e.g. emotional, embodied) often hard to elicit.

Specialised Practice

PARTICIPATORY DESIGN

Co-design, participatory design activities, speculative design *(e.g. storytelling, use of design probes, collective imagining, scenario-building).*

Context-sensitive design
Situated Knowledge

Women's Health Context

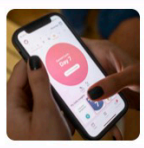
LIVED EXPERIENCE

Cultural, societal and emotional dimensions of women's health experiences *(e.g. bodily knowledge, emotional responses, cultural norms, and lived realities).*

Innovation

FEMTECH

Digital health innovations for female-health conditions *(e.g. mobile apps, wearables, trackers, platforms, smart devices).*



How can design practitioners better enact stigmatised narratives and realities of women's health lived experiences to design gender-responsive FemTech innovations?

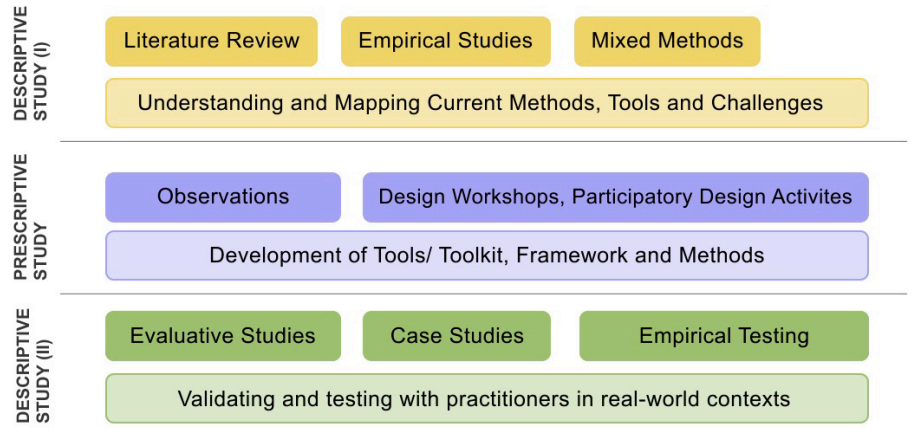
How sensitive health narratives, embodied and emotional forms of knowledge should be elicited and designed with in the FemTech design process?

What are the current challenges and limitations faced by design practitioners when eliciting and designing with women's health sensitive health topics and lived experiences?

Methodological Approach

The main aim of this research is to explore **how to amplify women's voices in the design process of FemTech, and surface lived realities and narratives often rooted in stigma, concealment and bodily knowledge.** The first phase is to explore and map the current tools and methods, followed by a secondary phase testing and developing tools and methods innovation teams need in participatory design activities to support lived experiences, collect stories, and form meaningful design insights on women's health experiences.

This project will follow a **Research into Design (RiD)** approach and **Design Research Methodology (DRM)** (Blessings, Chakabrati, 2002) employing mixed methods across three main studies: Descriptive (I,II) and Prescriptive.



Objectives

1. Review current FemTech design practices of professionals.
2. Explore what health innovators and design practitioners find hard about designing with sensitive topics in women's health tech projects.
3. Identify key issues and requirements that shape women's health experiences, how they are currently represented in FemTech innovations, and how these affect early FemTech design.
4. Develop new methods, interventions, tools or processes that help designers enact, surface and design with complex types of knowledge.
5. Test and improve these methods and tools through case studies with health innovators, design practitioners, start-ups and patients.

Expected Main Outcomes

The potential main contributions would consist in a gender-responsive design framework, health context-sensitive tools and methods, and the validation of such interventions to better support design practitioners and innovation teams designing with stigmatised narratives for socio-cultural relevant women's health digital technologies.

Bio

Diana Canghizer is a PhD Candidate in the Collective Innovation Lab, Dyson School of Design Engineering. She is a design researcher with experience in patient-centred design, inclusive design and user experience design. Her main research interests include novel design methods, women's healthcare (co)design, collective imagining and feminist human-computer interaction.

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CIL Collective Innovation Lab

Translating Stakeholder Expectations into Architecture of Conversational Systems through Flowcharts

> "This work maps participatory insights into structured system logic, utilising **flowchart-based design approach**."

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Supervisor: Prof. Rafael A. Calvo, Dr. Martina Di Simplicio

Abstract

Grounded in stakeholders' experiences and envisioned use cases of conversational agents, this work operationalises prior qualitative findings into a coherent agent framework. The resulting design illustrates a multi-agent system incorporating context-appropriate reflections, a profile identifier, and an activity recommender to support youth social prescribing.

Introduction

Social prescribing refers to a person-centred care approach that connects individuals to non-clinical, community-based resources [1, 2]. By co-designing care plans that align with individuals' needs, preferences, and goals, it acknowledges broader determinants of health and generates multi-level benefits for both individuals and the wider healthcare system [3]. Nevertheless, its implementation continues to face several challenges, particularly around coordination, engagement and accessibility [4]. Conversational agents have shown promise in innovating mental healthcare through natural language interaction, with applications spanning diagnosis, psychoeducation, and monitoring [5]. Building on prior work that identified stakeholder needs and design opportunities for applying conversational agents in youth social prescribing, this study presents the translation of those expectations into a structured, multi-agent system framework.

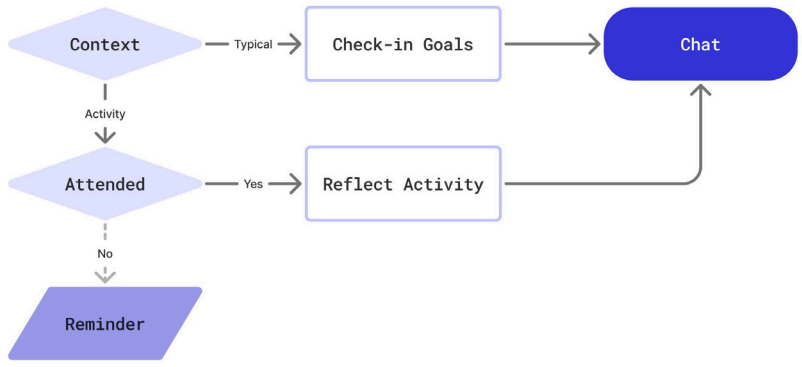
Methods

Two participatory design workshops were conducted with young people (n = 8) and link workers (n = 3). Each session was audio-recorded, transcribed verbatim, and analysed using thematic analysis to identify expected features. Based on participants' lived experiences and envisioned use case scenarios, individual flowcharts were developed in Figma to visualise how each feature might operate. The resulting diagrams were then translated into a unified framework outlining the logic of a multi-agent system.

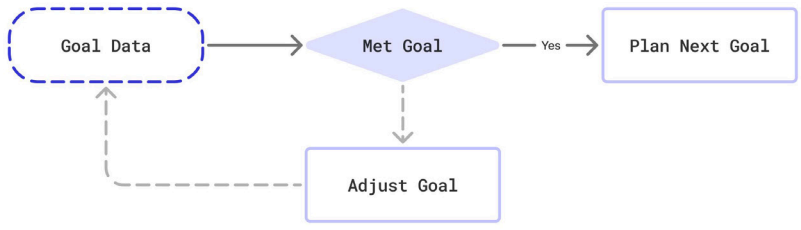
Results

Features	Description	Problem Space
Session Logger	A logging system to capture and organise session data, reducing time for recapitulation.	• Administrative burdens
Goal Tracker	A progress monitoring tool for sustained engagement with auto check-ins and reminders.	• Administrative burdens • Relational tensions • Engagement challenges
Interest Bank	A digital tool that enables young people identify or articulate their personal interests.	• Engagement challenges
Resource Directory	A searchable and regularly updated repository of community or local resources.	• Administrative burdens • System constraints
Activity Recommender	A tool generating tailored, culturally responsive, and age-appropriate activity suggestions.	• Engagement challenges

Features	Description	Problem Space
Personal Profiler	A personalised memory system that identifies needs, interests, mood, and causes.	• Personalisation gaps
Goal Planner	A collaborative goal-setting tool for step-by-step action plans and progress monitoring.	• Emotional barriers
Social Companion	A virtual companion between a friend and an assistant, for non-crisis, preventative support.	• Emotional barriers • Communication gaps
Reflection Mate	A constructive reflection tool for daily check-ins and social prescribing experiences.	• Emotional barriers • Communication gaps
Activity Connector	A tailored activity suggestion system, with practical guidance on how to participate.	• Logistical barriers • Navigational loads • Personalisation gaps

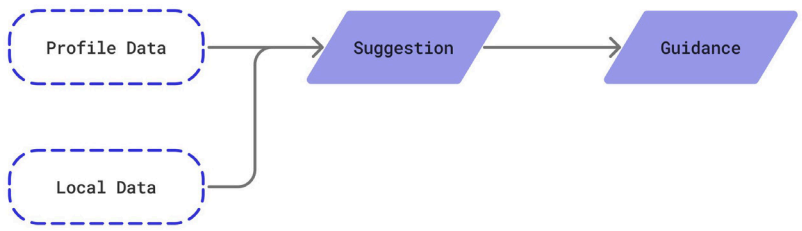


The analysis resulted in a set of feature-specific flowcharts, organised around three functional processes: forming datasets, deciding conversation mode, and extending conversation data. The agent begins by identifying the conversational context and determining its primary purpose. If the context does not involve a social activity, the system proceeds to a goal check-in sequence, a flow that determines whether goals have been achieved and suggests next steps. When the conversation concerns a social activity, the agent first checks attendance; if participated, it supports reflection on the experience, and if not, it generates reminders, as suggested by link workers.



Data from these interactions feed into flows that identify the user's interests, needs, and goals, supporting ongoing personalisation. In parallel, independent flows manage datasets like session notes and local resources.

Additional modules include an activity suggestion flow, which matches user profiles with local resources, and a support flow that provides informational or emotional supports to young people, according to the identified needs.



Conclusion

In conclusion, the core constructs of the system comprise goal reflection, activity reflection, profile building, and activity suggestion, supported by data structures for session notes and local resources. This multi-agent structure provides a modular foundation for developing and evaluating social prescribing support systems, particularly for young people.

References

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Understanding Multimodal Fusion through Cross-Modal Interaction

Gaoyun Fang & David Boyle
Dyson School of Design Engineering

Introduction

Background: The multimodal imbalance problem [1] occurs when certain modalities disproportionately dominate multimodal models, hindering the effective integration and utilization of information across modalities.

Problem: While existing approaches primarily attribute multimodal imbalance to the dominance of stronger modalities and focus on reducing competition, they often overlook a deeper structural issue: the trade-off between cross-modal interaction and modality competition.

Proposition: Our method, Cross-Interaction and Fusion Alignment (CIFA), combines early cross-modal attention with a dual fusion strategy using linear integration to suppress competition, non-linear layers to capture synergy, and contrastive supervision to align both modalities with target semantics. CIFA achieves 90% classification accuracy on the CREMA-D dataset and 97% classification accuracy on the AVE dataset, demonstrating its effectiveness in addressing modality imbalance.

Method

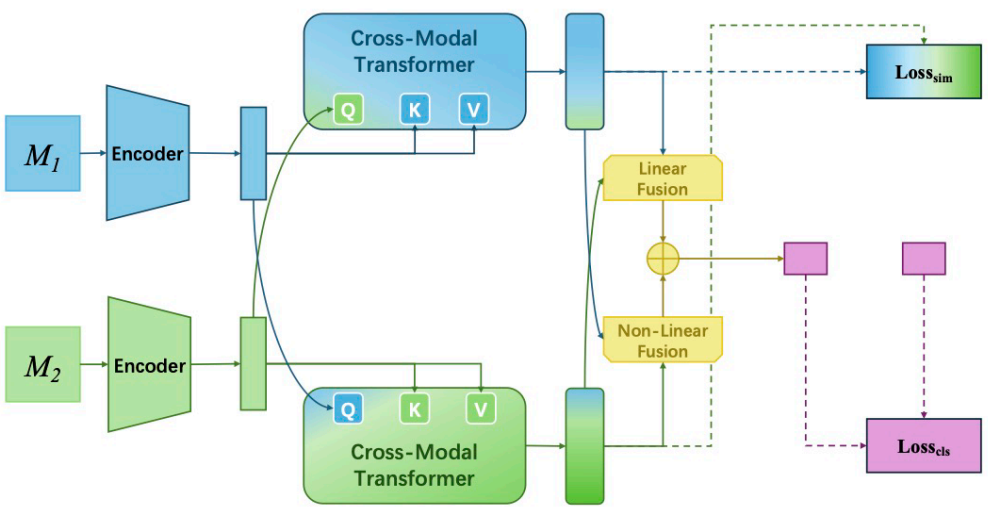


Figure 1: CIFA structure

Given two input modalities, we first extract high-level representations using pre-trained encoders (i.e., CLIP for video and CLAP for audio). To enable information exchange between modalities before fusion, we apply a cross-modal attention module, consisting of two attention layers (Cross-Modal Transformer in Fig. 1):

$$\hat{v} = v + \text{Attn}(v, a), \quad \hat{a} = a + \text{Attn}(a, v)$$

After cross-modal interaction, we decouple the fusion process into two separate stages. Linear fusion is performed via element-wise addition:

$$z_{\text{sum}} = \hat{v} + \hat{a}$$

Non-linear modeling is applied to z_{sum} using a shallow MLP to capture high-level synergy:

$$z_{\text{fused}} = \text{MLP}\left(z_{\text{sum}}\right)$$

We follow a similarity-based classification paradigm. Each class is represented by a fused textual embedding, obtained by summing projections from the CLIP and CLAP encoders. The model computes similarity between the fused multimodal representation and all class prototypes:

$$s_{i,k} = z^i_{\text{fused}} \cdot t_k$$

We supervise this with a temperature-scaled cross-entropy loss:

$$\mathcal{L}_{\text{cls}} = -\frac{1}{B}\sum_{i=1}^{B} \log \frac{\exp\left(s_{i,y_i}/\tau\right)}{\sum_k \exp\left(s_{i,k}/\tau\right)}$$

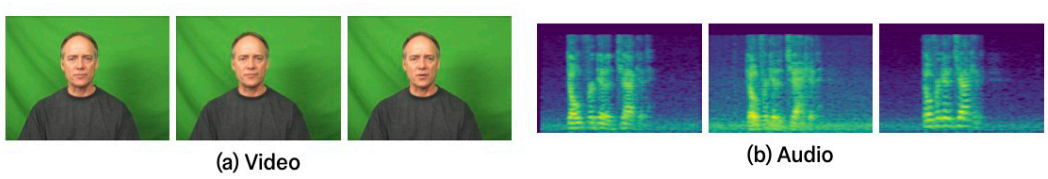
The total training objective is:

$$\mathcal{L}_{\text{total}} = \mathcal{L}_{\text{cls}} + \lambda \cdot \mathcal{L}_{\text{sim}}$$

Experiments

Dataset

Dataset: We evaluate our method on two benchmark datasets, CREMA-D [2] and AVE [3], using audio-video inputs and densely sampled frames for richer visual context.



(a) Video (b) Audio

Figure 2: Sample video and audio data from the CREMA-D Dataset [2]

Result

Figure 3: CREMA-D Results (Accuracy measures the proportion of correct predictions to total predictions)

Conclusion

We propose Cross-Interaction and Fusion Alignment (CIFA) as a simple and effective framework that balances modality interaction and competition for improved multimodal fusion performance. In particular, it reaches 90% accuracy in the CREMA-D dataset, surpassing existing reported baselines [1] by 61% and reaches 97% accuracy in the AVE dataset, surpassing existing reported baselines [4] by 75%, indicating that further exploration of interaction and competition trade-offs in multimodal model training may be worthwhile.

References

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CLIMATE RISK IDENTIFICATION IN MEDIUM-SIZED FIRMS IN THE UK

Contact: Cece Koczias,
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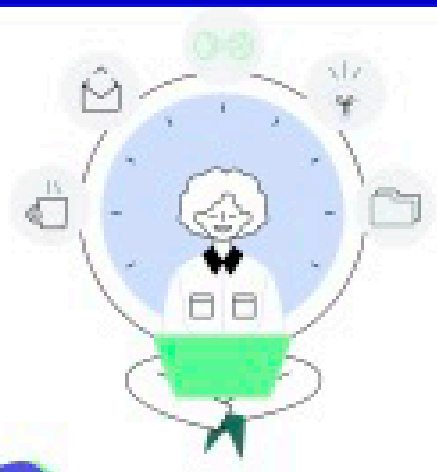
Supervisor: Pelin Demirel

1 The Problem

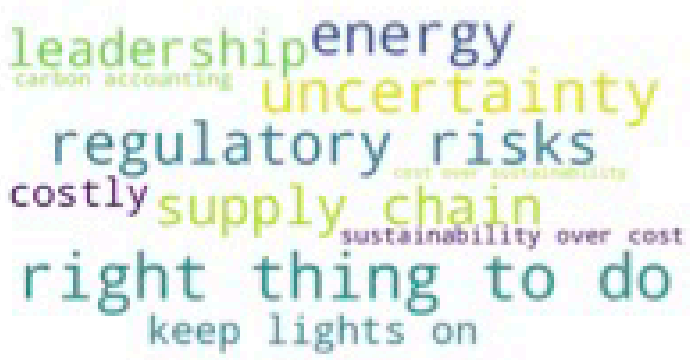
- Climate risks (CR) are growing, but medium-sized enterprises (MSEs) are overlooked in both research and policy. MSEs are too large for SME exemptions, too small for large-firm resources, so:

How do MSEs identify climate risks?



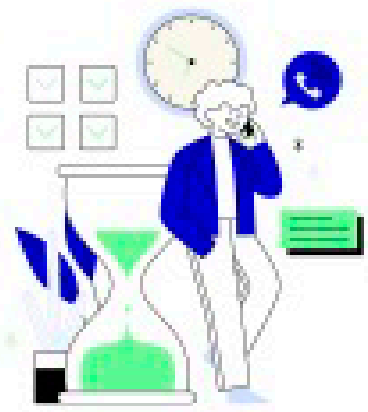
2 Methodology

- 40 semi-structured interviews with MSE owners/managers and sector experts using qualitative thematic analysis of interview data.



3 Key Triggers for CR Identification

- Supply Chain – Global disruptions and client demands expose climate risks.
- Energy – High costs push firms to act on energy efficiency.
- Regulation – Unclear policies delay climate action.



4 Research Impact

- Exposes unique climate risks for medium-sized firms, calling for tailored policies.
- Shows how MSEs blend informal and formal tools for climate risk management.
- Introduces a sensemaking-based hybrid framework addressing key research gaps.
- Offers practical guidance for policymakers and support bodies.

5 Propositions

- Tailored policy interventions (i.e. stable policy roadmaps, scaled regulatory guidance).
- Supporting the formalisation of climate risk tools.
- Enhancement of skills for improved utility of heuristics as a strategic tool.

6 Stay Connected

- If you're working on climate risk, sustainability, or SME strategy — let's talk!
- If you know any MSEs, please help out by making introductions — let's network!

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Transsomatic: Bodily Mutation through Autobiographical Design of Vocal Practice

Ephemerides is digital musical instrument using a microphone, a voice coil transducer, and a MaxMSP feedback system.

June Kuhn, j.kuhn24@imperial.ac.uk
Andrew McPherson

Abstract

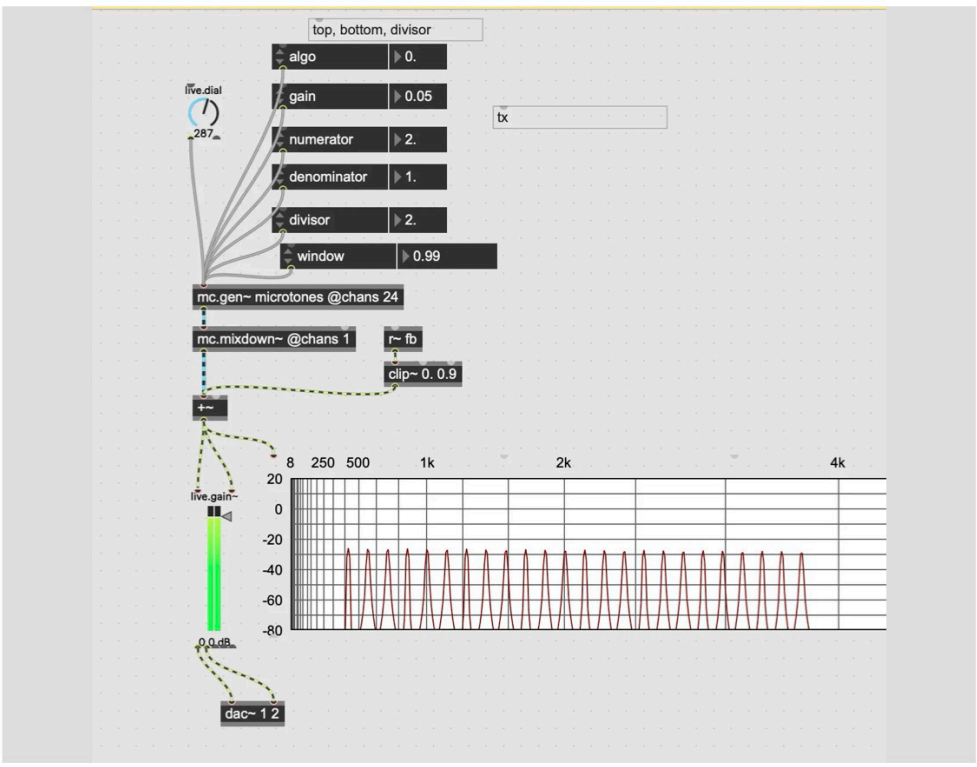
Trans voice is a complex and often misunderstood phenomenon that necessitates new understandings in technology, society, and culture. Through the lens of digital musical instrument design, trans voice can be reframed as a phenonema co-consituted from more-than-human entanglements of body, society, culture, and technology, with implications of simultaneous design of technology and the body. I present Ephemerides, a digital musical instrument that incorporates the body as a resonant filter in a feedback loop, as a design primarily for myself in my trans vocal practice. As a research probe, this instrument grants me exploration with my own creative practice, my voice in my gender vocal training, and my understanding of gendered characteristics of voice in performance.

Introduction

Discourse on intention body mutation within HCI is generally limited to clinical research, with less consideration towards artistic, cultural, and social practices. Paradoxically, queer and disabled people, especially for transgender, intersex, and congitally disabled, are seen as a 'mutated' population that should be corrected through modern techniques, and procedures happen often without consent [8]. Trans voice practices are a particular form of purposeful bodily mutation in which medical literature defines as vocal training or surgery in order to use their voice that better fits their needs [1]. This research looks at a potential alternative in politics for somatomorphic practices, situated in designing a digital music instrument for the author's own purposes.

Methods

- Autobiographical Design - field notes, voice recordings, creative practice
- Soma Design - Noticing [4]
- Evaluation Through Performance - live on stage, live in a gallery, and live streaming online



Overview

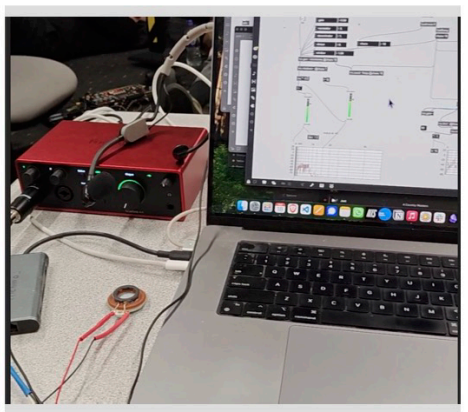
Ephemerides is a prototype of a digital musical instrument consisting of a headset microphone, a handheld voice coil transducer connected to a powered amplifier, and a MaxMSP patch that implements the feedback system. The patch plays through the transducer a series of additive sine waves at different frequencies according to various microtonal parameters, which when pressed against the throat, is picked up from the mouth with the microphone.

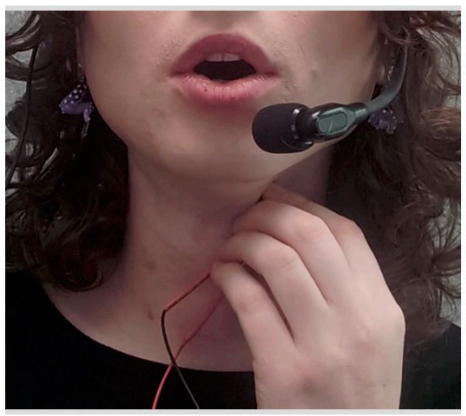
Discussion

Ephemerides as an effect of defamiliarising vocality. Use of vocal cords and speech are no longer primary components of music making and musicality. Playing Ephemerides is an engagement with vocality, even though the intention was to focus on resonance and to instrumentalize a different part of the vocal apparatus. Ephemerides in some capacities move the voice towards the keyboard, and in other ways is completely unlike a keyboard without a black and white key visual interface.

The primary way of selecting pitch with Ephemerides is derived from transgender voice training practices, but gendered characteristics are not heard directly. Though the perception of gender in voice could be thereoticaly attributed to technical parameters like resonance, vocal fold mass, or pitch variability [2], the sonification of these parameters through Ephemerides depends on knowledge of these parameters. It seems that recognising gender with this instrument is less important than the role of the performer's ability to manipulate gendered characteristic in their voice to acheive a desired effect. It reflects Susan Stryker's analysis of the Monster as a cultural figure in the explorations of ambiguous states [7].

Further, I would argue that Ephemerides is a crip design as it was autobiographically motivated to make sense of my own vocal dysphoria. I do so in a way that doesn't assimilate my voice into a stereotypical feminine speaking tone, and to expand on possible vocalities through technology. Crip theory provides a powerful narrative in developing trans technology, suggesting that difference in bodies is an aspect to be celebrated [3,5]. In this case, the performer is using trans vocal techniques in order to find musical gesture. In a sense, technologising and instrumentalising voice has created this focus on technique, practice, and originality that shifts thinking from the need to 'pass'.





Conclusion

Digital Musical Instruments can serve as cultural probes for investigating new methods of design practice, making music, and empowering disadvantaged communities [6]. Ephemerides, through autobiographical design stemming from interests in microtonal synthesis and trans voice technology, illuminates some of the hidden connections between gender, music, technology, and bodies. It lays the groundwork for a politics for willful bodily mutation that prioritises cultural integration over medical pathologisation.

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Spatial release from masking and listening effort: differences between binaural and free-field presentation

Nicola La Magna[1], Katarina Poole[1] and Lorenzo Picinali[1]
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"DO WE HEAR THE SAME WHEN USING HEADPHONES OR LOUDSPEAKERS?"

1 Introduction

Understanding **speech** in noisy environments is a crucial aspect of auditory perception and communication in everyday life. Neural and structural specializations have evolved to perform this complex task. For instance, speech intelligibility in such conditions benefits under **Spatial Release from Masking** (SRM) **[1]**, which refers to the improvement in understanding speech when the target and masking sources are spatially separated.

While SRM has been widely studied, its **cognitive demands** and benefits under different **rendering conditions** - including sounds rendered through **loudspeaker systems** or binaurally via **Head-Related Transfer Functions** (HRTFs) - are less explored.

Therefore, our goal is to investigate **differences (i.e., behavioural and neurophysiological)** between binaural rendering and free field presentation, while also evaluating **listening effort** (pupillometry) as a **valid metric** for spatial hearing tasks. We hypothesize greater accuracy and reduced effort in the loudspeaker condition (i.e., individual real HRTF).

2 Methodology

A task including a SRM paradigm, adapted from **[2]**, was employed to investigate speech intelligibility over headphones (i.e., KEMAR HRTF) and loudspeaker rendering.

- **Target (T)**: "Ready Baron go to [colour] [number] now" – **always presented at 0° Az**
- **Maskers (M)**: "Ready [callsign] go to [colour] [number] now" - **0°Az 0° El or at +-60° Az 0°El**

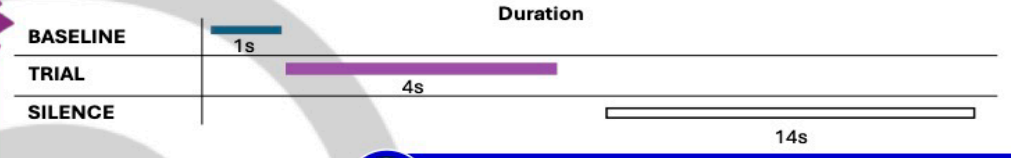
Loudspeaker rendering: custom one-way medium-density–fibreboard cabinets mounting a full-range Peerless 8309873-in driver and operating in a frequency range between 100 Hz and 20 kHz.

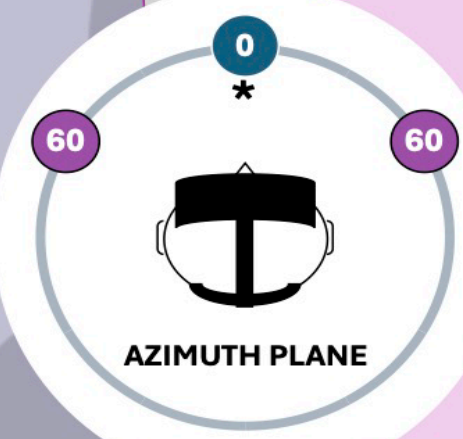
Headphones rendering: a pair of Sennheiser HD 650 with spatialisation applied via the 3Dti-toolkit **[3]** VST for MaxMSP using a mannequin non-individualised HRTFs (i.e., KEMAR).

Stimuli: CRM corpus at 96kHz 16bit.

2 renderings x 20 repeats x 2 **T-M** locations (0, +-60)

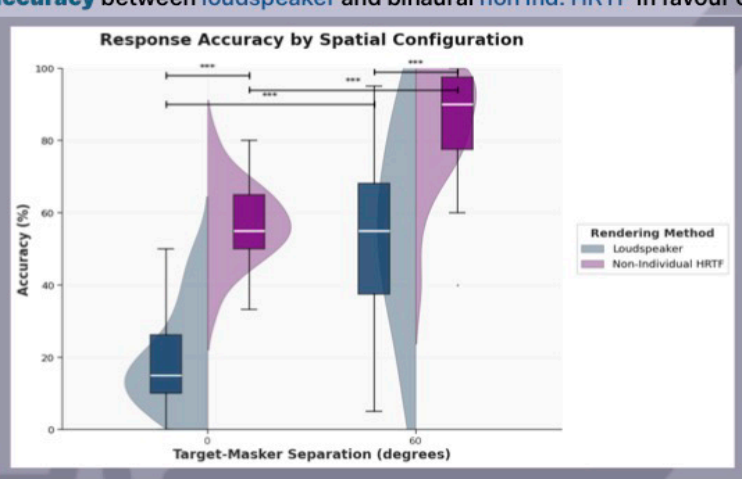
All the participants were wearing an HTC VIVE FOCUS VISION HMD with built-in eye tracker.

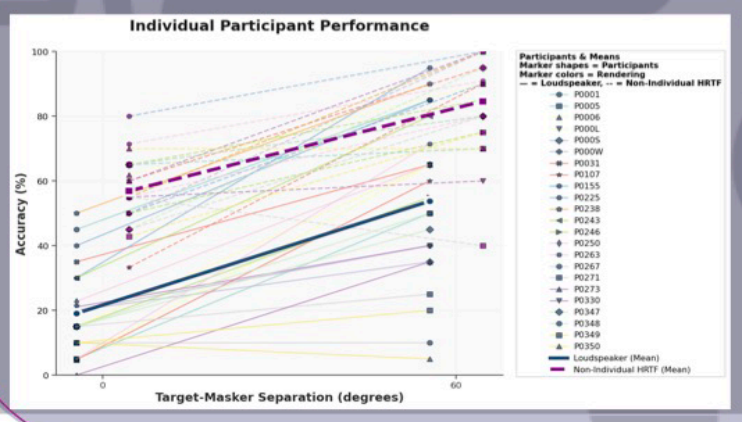




3 Results - behavioural (n=23)

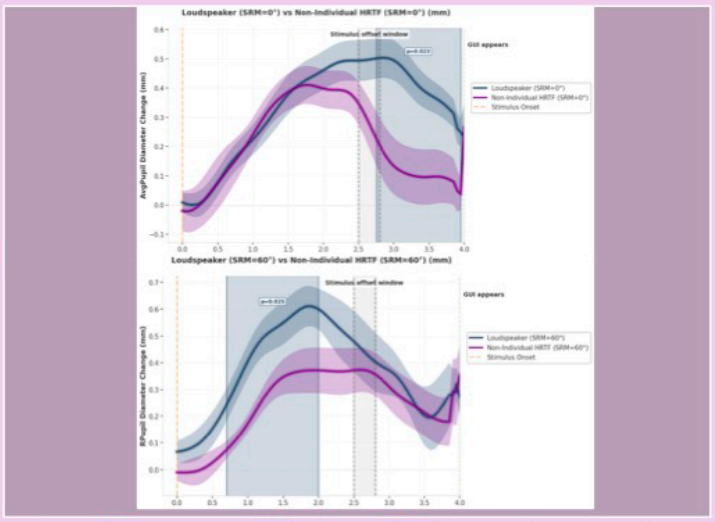
Differently from what we expected, pilot results seem to show **differences** in **accuracy** between loudspeaker and binaural non ind. HRTF in favour of the latter.



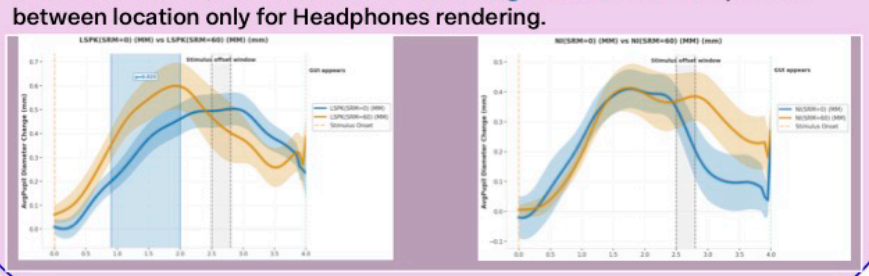


4 Results – pupillometry (n=23)

Differences in **listening effort** seem to be present between loudspeaker and non. ind. HRTF, reflecting the behavioural response.



On the other hand, **no differences** in **listening effort** seem to be present between location only for Headphones rendering.



5 Discussion

- Consistent with previous research on the topic, the preliminary results suggest a **benefit of spatialisation** for **both rendering** conditions. However, differences in **effort** seem to be present between T-M location (i.e., 0; +-60) only for the loudspeaker conditions. This suggest a saliency attentional locking when hearing free field. This phase locking effect may be lost when simplifying the system virtually with headphones. Moreover, **headphones** seem to provide an intelligibility benefit when spatial cues are absent.
- Loudspeaker based rendering suggest a **higher effort** and **less accurate** responses when compared to the non-individual HRTF binaural presentation.
- This results would raise up **questions** about the transferability effect between virtual and free field presentation for hearing skills training.
- Using **pupillometry** seems to be a valid method to assess and evaluate hearing responses to different rendering conditions. The next step would be to involve this method to address **HRTFs personalisation** benefit.

6 Conclusions

- People may need to take into account these differences in speech intelligibility when **deciding which rendering method to employ in their applications.**
- Speech production and perception with loudspeaker is influenced by **non linearities** that affect the free field presentation of sounds. These non linearities **are processed with increased cognitive effort** by the auditory system, regardless the presence of individual cues.
- To what extent can people **transfer trained abilities** from one domain to another?
- To what extent **can people generalise the skills learnt** in an impoverished situation to a different one?
- How can **real time assessment of pupil dilation** be used to as an index to reduce cognitive effort in free field listening environments?
- **Reverberation?**

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8 Bio

Nicola La Magna is a PhD student in the **Audio Experience Design (AXD)** group. His research include the application of Virtual Reality and Augmented Reality trainings, evaluating their features and addressing their involvement in procedural and perceptual learning. Moreover, a specific focus will be on the transfer of hearing performance from VR to real-life (i.e., free field) conditions with respect to Normal hearing and Cochlear Implant users. His research will blend both engineering techniques and psychophysiological assessments to reach the intended aims.

CHERISH Cochlear implants & spatial hearing

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Pathways to Net-Zero: A Systematic Review of Corporate Climate Strategy, Mechanisms and Performance

> “From Pressure to Performance, Mastering the Mechanisms.”

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Supervisors: Pelin Demirel, Peter Childs

Abstract: Since the Paris Agreement, firms have faced increasing pressure to reduce emissions and adopt sustainable practices, leading to a range of climate strategies. This study reviews 64 high-impact journal articles, identifying three core climate strategies—governance, innovation and technology, and external resource integration—along with nine underlying micro-level mechanisms. It also proposes a contextual heterogeneity framework based on industry carbon intensity and firm capabilities to explain variations in firms’ financial and environmental performance under their climate strategies. This research shifts the academic focus from whether strategies work to which conditions strategies work.

Research Questions

1. What are the key climate strategies that firms employ, and through which mechanisms do these strategies affect firms’ financial and environmental performance?

2. What explains the variation in the performance outcomes of corporate climate strategies?

Methods

Following PRISMA guidelines, 64 high-quality empirical studies from 2016–2025 were collected, screened, and cross-validated across multiple databases to ensure rigorous and unbiased evidence synthesis.

Findings

1. Corporate climate strategy domains

- Governance Strategy- e.g. Environmental disclosure; incentives
- Innovation & Technology Strategy-e.g digitalisationn
- External Resource Integration Strategy- e.g. green M&A

Strategies	Mechanisms	Financial Performance	Environmental Performance
Governance strategy	*Signalling of reduced information asymmetry*	**Generally positive:** Enhances market trust, firm valuation Lowers capital costs	**Controversial:** Disclosure may be substantive but can also be symbolic or greenwashing.
	Re-orientation of corporate goals	**Positive:** Stimulates long-term green investment Enhances sustained firm value	**Positive:** Strengthens board involvement Supports long-term emission reduction goals
	Reduction of agency conflicts	**Positive:** Improves operational efficiency and resource allocation Increases market value	**Positive:** Reduces carbon intensity Promotes internal innovation and energy saving
Innovation and technology strategy	*Improvement of efficiency*	**General positive:** Lowers operating costs Energy costs may show an inverted U-shape	**Positive:** Reduces emissions Optimises energy structure Advanced technologies phase out high-polluting firms
	Improvement of absorptive capacity	**Positive:** Increases returns from green innovation	**Positive:** Increases pollution reduction
	Enhancement of transparency and connectivity	**Positive:** Reduces capital costs Gains a green reputation premium	**Positive:** Improves risk identification and green governance Holding back greenwashing
External resource integration strategy	*Leverage of external resources*	**Positive:** Alleviates financing constraints Enhances long-term profitability and market value	**Positive:** Improves risk identification and green governance Holding back greenwashing
	Operational integration	**Long-term positive:** Boosts operational efficiency Increase supply chain competitiveness	**Long-term positive:** Lowers carbon intensity, though environmental benefits often show time lag
	Strategic adjustment	**Mixed:** Green M&A brings positive returns Outsourcing or expansion in emerging markets shows uncertain outcomes	**Mixed:** Green M&A cuts emissions Outsourcing may trigger emission rebound

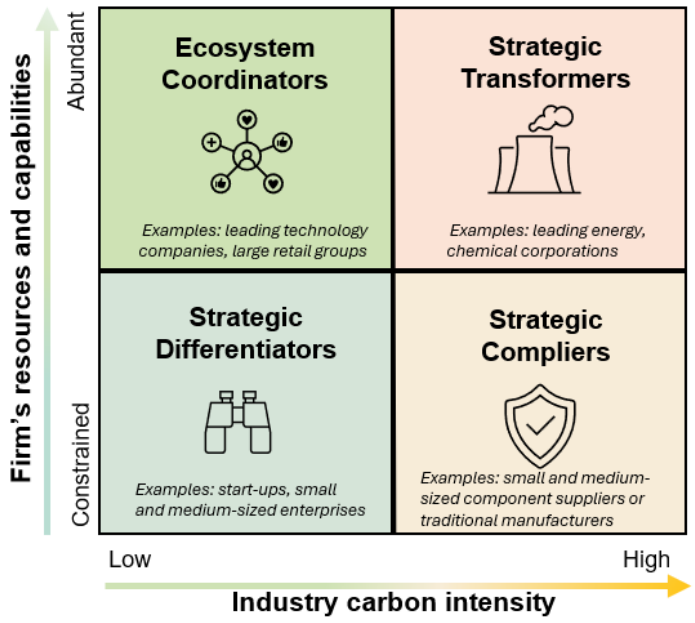
2. Environmental–Financial Performance Relationship

- **Synergies exist:** Climate strategies enhance efficiency, reputation, and market opportunities [1].
- **Trade-offs are also real. :** Short-term costs may reduce profits despite long-term value [2].
- **Context-Dependence:** The link between environmental and financial performance is not linear. It can show U-shaped or paradoxical patterns by performance, metrics, and perception [3].

A Contextual Heterogeneity Framework

(1) Strategic Transformers
Disruptive tech • Value-chain integration
→ Long-term gain, short-term cost
(2) Ecosystem Coordinators
Market influence • Governance alignment
→ Stable gains via efficiency & reputation

Abundant resources and capable firms



(3) Strategic Differentiators
Niche innovation • Reputational focus
→ Moderate best, over-investment hurts
(4) Strategic Compliers
Passive compliance • External assist
→ Low returns, possible “green penalty”

Resource-limited and capability-constrained firms

Bio

Shihui Liang is a first-year PhD student at the Dyson School of Design Engineering. Her research explores how firms respond to climate change through inter-organisational collaboration and strategic management.

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The Role of Rituals in Hybrid Work Environments: A Integrative Review

" The first integrative review synthesising the function of rituals in employee experience and organisational culture within hybrid work environments. "

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Introduction

Hybrid work arrangements have become normalised feature of employment in the post-pandemic era. It combines traditional in-office work with the option to work remotely to provide great autonomy and flexibility [1].

Rituals are non-instrument behaviours [2], serving as a subtle yet powerful way to create meaningful experiences for employees and organisations. Rituals have been embedded in various stages of the employee journey ranging from onboarding (e.g., welcome lunches) to retirement (e.g., recognition ceremonies), while has primarily focused on traditional workplace settings [3]. It thus remains unclear if and how rituals show up in hybrid work environments.

Thus, the aim of this integrative review is to document the understanding of rituals in hybrid work environments and its potential in supporting employee experience and organisational culture.

Methods

We conducted an integrative review following the PRISMA framework, searching across business, management, psychology, and grey literature databases. Boolean operator 'AND' was used to combine two groups of keywords: (a) work environment and (b) ritual-related terms. After screening, 53 papers were identified for coding and analysis.

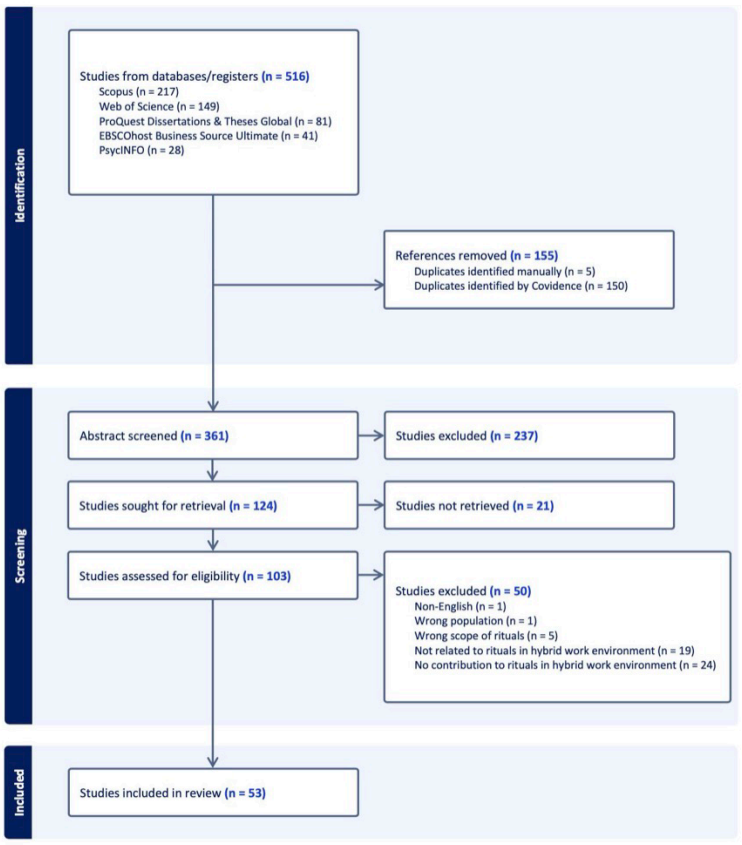


Figure 1: The workflow for identifying, screening and including studies in the review, in accordance with PRISMA 2020

Results

We first conceptualised workplace rituals and mapped their functions across the entire employee journey in two distinct work scenarios: traditional office and home-based environments. A comparison of the rituals in these two settings revealed that home-based rituals are predominantly individual-level practices that facilitate work–life role transitions, whereas rituals in traditional offices are largely collective, fostering social bonding among employees.

By synthesising findings from both scenarios, we identified seven key functions of workplace rituals in shaping employee experience and organisational culture (see Figure 2).

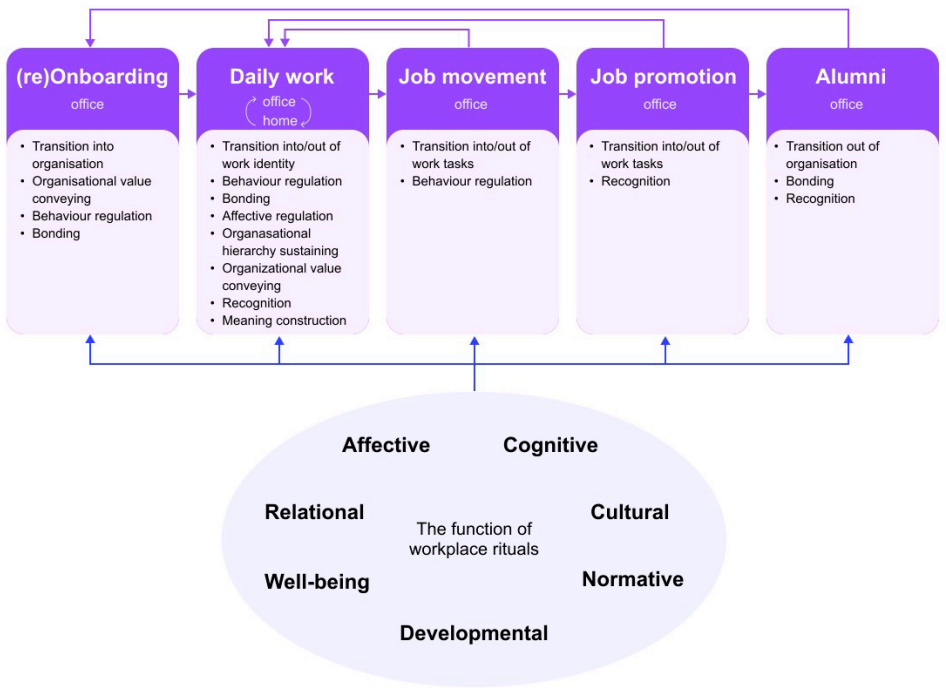
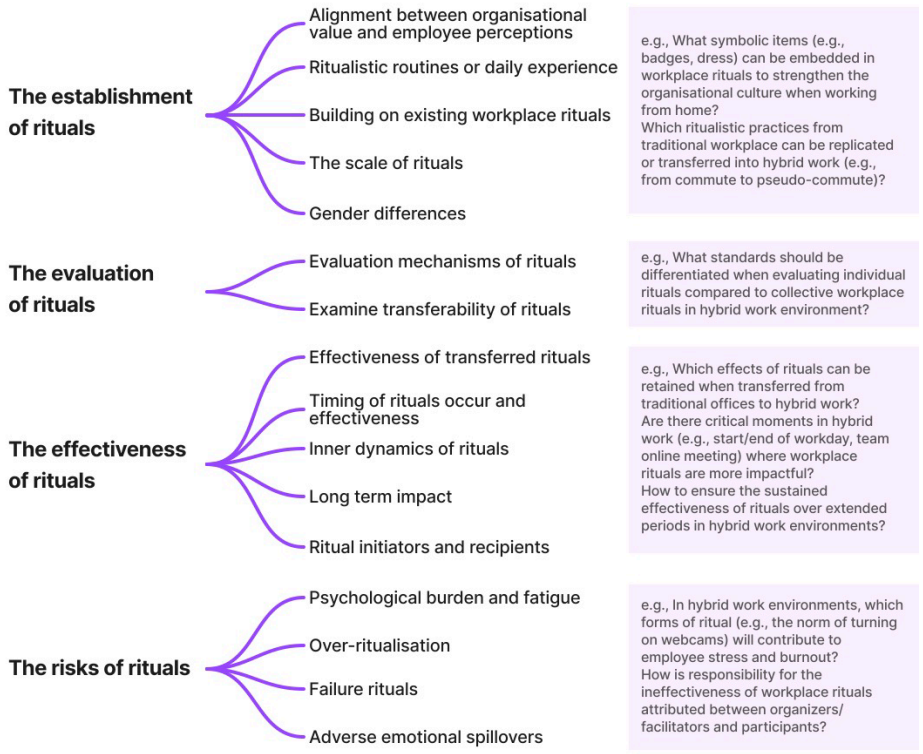


Figure 2: The function of workplace rituals in shaping hybrid employee journey

Research agenda

Drawing on a synthesis of prior studies and their limitations, this review identifies five key focuses of workplace rituals, related research topics and examples of questions as follows.



Bio

Mingnan Lin is a PhD student in the Interaction Foundry at the Dyson School of Design Engineering. Her research focuses on ritual-related interventions and human behavior change, particularly on how such interventions can be designed and implemented in hybrid work environments.

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Reconsidering Entrepreneurial Ecosystems: A Problematising Review and Way Forward

Entrepreneurial Ecosystems describe "place-specific entrepreneurship-led development" (Harrison 2025)

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Supervised by Pelin Demirel and Leila Sheldrick

Abstract

- **What is an entrepreneurial ecosystem? How is this metaphor understood and used by researchers?**
- Aim: examine conceptual foundations and usage in research.
- Key assumptions of EE: **(A1)** the entrepreneur as the unit of analysis; and **(A2)** entrepreneurs leading ecosystems such that they become self-organising.
- Research trajectories: **(T1)** a drive towards measurement; and **(T2)** viewing them as complex systems.
- Critique: Limited explanatory power of current EE approaches.
- Way forward: theoretical clarification to strengthen explanation.

Introduction

- There's growing interest in Entrepreneurial contexts
- Entrepreneurial Ecosystems metaphor is increasingly used across policy, practice, and research
- But, the metaphor has conceptual and explanatory problems
- This is a critical review to unpack research assumptions and trajectories

Methods

- Four principles of a problematising approach guided this review:
  - **(1)** Reviewer reflexivity; **(2)** Selective breadth; **(3)** Problematisation; and **(4)** Less is more.
- We conducted an initial systematic review methodology using two constructs: **Entrepreneurial Ecosystems** and **Regional Development**; and two databases: **Web of Science** and **Scopus**.
- Filters: English; 2020+; rated 3+ CABS.
- Yield: **52-papers**. For discussant papers we snowballed from the 52.

Results

EE's assumptions (A) and their research trajectories (T):
- **A1**: Entrepreneurial Centrality → **T1**: Drive Toward Measurement
- **A2**: Ecosystem Self-Organisation → **T2**: Complexity Thinking

Problematisation of Assumptions and Trajectories:
- **A1**: High-growth bias and exclusion of mundane firms
- **T1**: Measurement over causality and weak explanation
- **A2**: Political implications and overlooking policy and government
- **T2**: Complexity thinking conflates structure and agency

All mean EE research reach an explanatory impasse

Discussion

Assumption:
- Theoretical explanation is necessary to support and enable entrepreneurs.

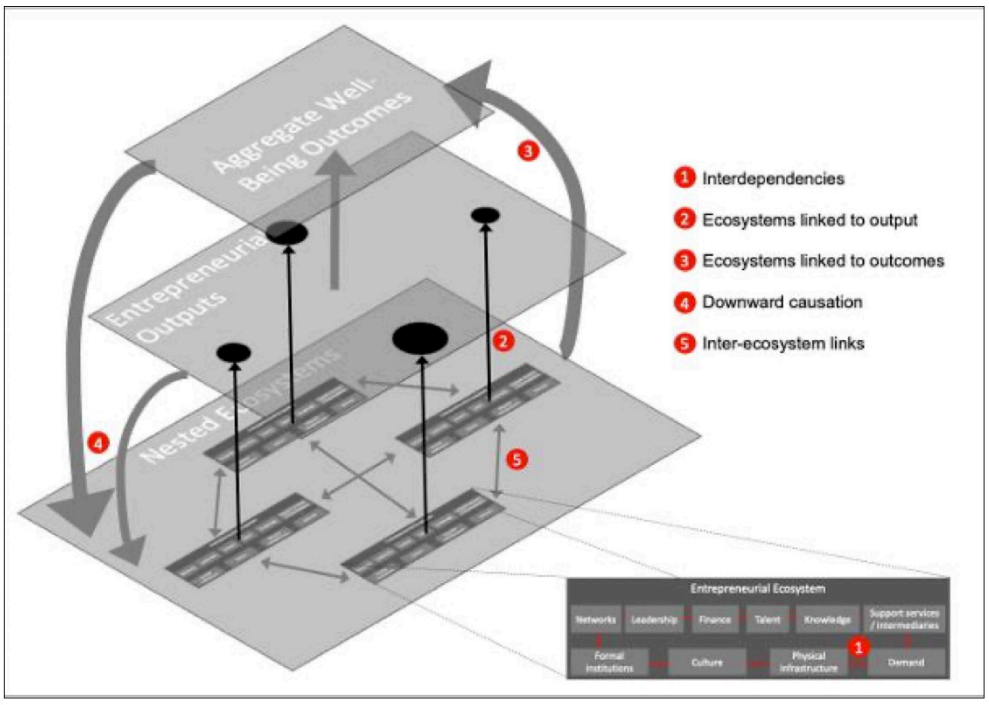
EE:
- Problem: EE research lacks causal and analytical clarity.
- Consequence: Inability to explain entrepreneurial contribution to regional development.

Way Forward:
- Strengthen EE's explanatory power
- Retain EE's Critical Realist foundation to theorise causal mechanisms.

Reinterpret Wurth et al.'s (2022) EE framework (image below):
- Their causal mechanisms are better understood as contingent processes (Yeung 2024).
- Use to leverage existing literature and deepen causal investigation

Therefore...
- Position EE as a middle-range theory linking micro and macro dynamics.

Apply ABC Model of Entrepreneurship (Ramoglou & McMullen 2024):
- Desired future (A) is pursued by action path (B) and enabled by the necessary conditions (C).



Conclusion

Aim: Clarify the EE concept and strengthen research and policy impact

Problems:
- **A1** & **T1**: Empiricist focus on HGFs, this limits causal explanation.
- **A2** & **T2**: Self-organisation and complexity obscure policy and agency.

Solution:
- Reframe EE as a middle-range theory using the ABC model of entrepreneurship.

Execution:
- Framework guides empirical research across thesis.

Bio

Bryn Medd-Sygrove is a 2nd-year PhD student at the Dyson School of Design Engineering and is funded by the Centre for Sectoral Economic Performance (CSEP). He has a background in Political Economy and industry experience at a startup accelerator and as a researcher for institutional investors.

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Designing for Better Weak Tie Human Connectivity Outcomes

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Weston Baxter

"There are 8 types of interaction-initiating conversation structures"

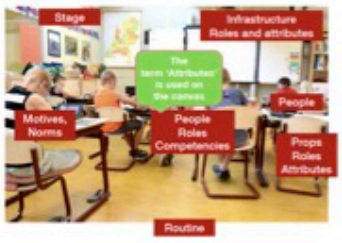
Introduction

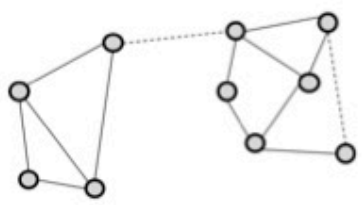
The weak tie interactions we have those on the periphery of our network play a crucial role in professional and personal life outcomes (Granovetter (1973). Yet these moments are declining in both frequency and quality, especially in organisational settings shaped by technology, remote work, and social norms that reduce informal exchanges. This research investigates how weak ties are formed, what enables or blocks them, and how we can design more effective social connection experiences. Through observational and interview-based fieldwork at curated networking events, I identify distinct types of interaction-initiating structures, break down the role of social and physical settings, and offer a framework to support designers in fostering better human connection outcomes.

Methods

This study employed a qualitative, ethnographic approach to examine how weak tie interactions are initiated and shaped in real-world settings. Fieldwork was conducted at a multi-day summit designed to foster connection among members of a global community. Data was collected through participant observation, semi-structured interviews with 18 attendees, and archival materials including event communications and digital group interactions. Observations focused on the environmental, social, and conversational elements that shaped how people approached and engaged with one another.

Data were analysed through an iterative process, whereby the observation and interview data were coded and examined for recurring patterns. The first author reviewed event timelines and field notes to capture all observable instances in which interactions occurred. During interviews, participants were asked to reflect on the different settings where they had experienced interactions—both in formal sessions and informal moments between them. The author's and participants' lists of interaction settings were then collated and sorted by interaction type to reach saturation. Behaviour Setting Theory (Barker, 1968; Aunger & Curtis, 2016) was used as an analytical lens to distinguish the physical and social features of each setting and to identify the enablers, barriers, and mechanisms influencing weak tie interaction outcomes.





Results

Study 1 revealed eight types of interaction-initiating script structures, grouped into four overarching categories based on the underlying motive and mechanism of interaction initiation. Each structure reflects different pathways into weak tie conversation and reveals specific design affordances.

Category of Scripts	Script Types
Instrumental / Need-based Interactions fulfill a functional or emotional need.	**Premediated Need -** The initiator enters the setting with a clear need (e.g. a lift, a costume, emotional support) and seeks others who can fulfil it. Interaction is intentionally and directly requested, with a functional purpose.
	Context-Emergent - The initiator's need arises spontaneously from the environment (e.g. noticing someone has snacks or information), triggering a social approach. The setting creates the script; the connection emerges reactively and responsively.
Attraction / Curiosity-based- Interactions prompted by visible signals or resonance that spark interest.	**Signal Scripts -** One person notices a visible cue (e.g. behaviour, clothing, possessions, status) from another and initiates based on this perceived affordance. These are intentional, often targeted approaches driven by curiosity, recognition, or attraction.
Facilitated Interactions enabled through structured roles or introductions that lower social friction.	**Introductory Scripts -** A third-party (host, facilitator, peer) introduces A to B, often providing a reason for the connection. This creates immediate permission, legitimacy, and a shared social frame.
	In-Role - Participants are guided into interaction through facilitation or structured activity (e.g. paired prompts, group tasks). Roles and instructions shape behaviour, offering safety and a ready-made script for conversation.
Serendipitous Interactions maintain or explore social affiliation by responding to shared environment, norms, or proximity cues	**Low-Affiliation Local Context Scripts -** Initiated through observations about the immediate environment (e.g. "This queue's taking ages"), these scripts rely on serendipitous proximity and light, situationally-relevant engagement. Suitable where norms allow but do not require interaction
	Global Phatic Scripts - Culturally universal openers (e.g. "Where are you from?") used in settings where light interaction is socially expected. These scripts help maintain affiliative norms and reduce awkwardness in serendipitous co-presence.
	Shared Context Scripts - Initiated through references to a broader shared experience (e.g. "What's been your highlight of the retreat so far?"), these interactions leverage deeper affiliation, using serendipitous proximity to build more meaningful engagement.

Discussion

This research contributes to a growing body of work that explores how weak tie interactions (those between acquaintances or strangers) can be better supported through intentional design.
The first study surfaces eight distinct interaction-initiating script structures, each shaped by a combination of roles, proximity, norms, and conversational prompts. The results also reinforce the importance of thinking beyond individual agency. Weak tie connection is not only about personality or motivation but shaped significantly by roles, norms, affordances, and scripts embedded in the environment (Aunger & Curtis, 2016; Schank & Abelson, 1977)

Designers of human connection experiences (e.g. in events, organisations, or digital platforms) can intervene by shaping the physical, social, and temporal conditions under which people meet. Future work will focus on building on this descriptive understanding to generate prescriptive tools and frameworks that support designers in navigating these complexities. Study 2 will examine the influence of physical, social, and technological features within real-world behavioural settings, aiming to distil generalisable principles that can support weak tie formation. Study 3 will apply and evaluate these insights by developing practical tools that help designers scaffold meaningful connection across diverse contexts, from organisational events to everyday encounters.

Conclusion

This research advances our understanding of weak tie formation by identifying and articulating a typology of interaction-initiating script structures and the design conditions that support them. By bridging behavioural theory, ethnographic research, and design practice, it moves toward a more prescriptive model for supporting social connection in organisational contexts. In doing so, it contributes to the broader field of design for human connectivity, extending foundational work on weak ties (Granovetter, 1973), behavioural settings (Aunger & Curtis, 2016), and finding and forming connections (Mandeno, 2022). As weak ties become increasingly scarce yet vital, this work will advance the field of design for human connectivity and lay the groundwork for the development of prescriptive tools to support designers and practitioners in cultivating more effective connection experiences.

Bio

Georgie Nightingall is a PhD candidate at the Dyson School of Design Engineering, Imperial College London. Her research investigates how to design for meaningful human connection, with a focus on weak tie interactions in organisational and everyday settings. Using behavioural science, conversation analysis, and ethnographic methods, she explores the social and environmental conditions that shape how people interact. Alongside her academic research, Georgie designs and teaches programmes on the art and design of human connection. She supports individuals, organisations, and communities to foster deeper dialogue, build trust, and cultivate social fabric. Her work bridges theory and practice, blending research, facilitation, and experiential design to make connection more intentional, accessible, and impactful.

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UKRI Economic and Social Research Council

TOWARDS ACCESSIBLE INDIVIDUAL HEAD-RELATED TRANSFER FUNCTIONS FOR SPATIAL AUDIO APPLICATIONS

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“Your ears' shapes influence the way you spatially hear the world of sound around you”

Introduction & research aims

Head-Related Transfer Functions (HRTFs) are unique **acoustic filters** that characterise how sound waves from **locations around a listener** interact with their **anatomy**, including the **shape**, **size**, and **position** of the **ears**, as well as the **head** and **torso**.

Individual HRTFs are fundamental in immersive audio as they can result in enhanced rendering quality, higher **sound localisation** accuracy and less **front-back confusions** [1].

Acoustic HRTF acquisition methods require specialised equipment and **expertise** [2], which pose significant **accessibility** challenges.

High-resolution **3D scanners** and modelling offer a pathway to numerically synthesise HRTFs using tools such as **Mesh2HRTF** [3]. However, the **high cost** of 3D scanners restrict their **accessibility**.

Photogrammetry can be seen as an alternative, being more accessible and affordable and has been explored to obtain HRTFs via the combination of **Photogrammetry Reconstruction (PR)** and **HRTF synthesis** [4].

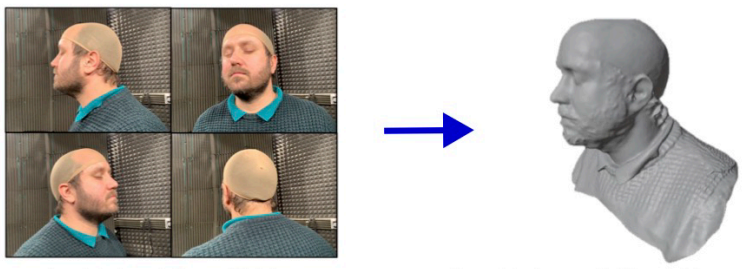
The goal of this study is to **set the baseline performance** of **PR synthetic HRTFs** compared to High-Resolution **3D scan synthetic HRTFs** [5].

Methodology

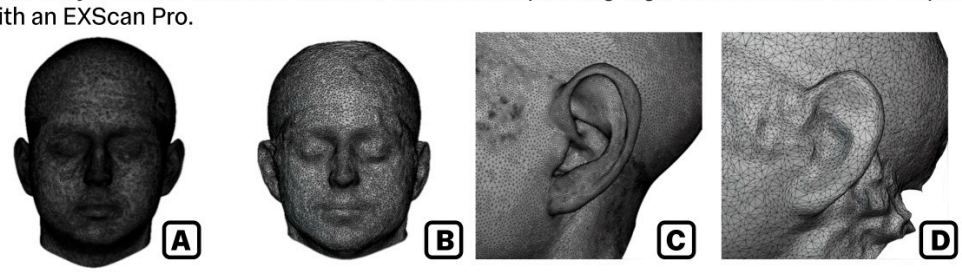
Photogrammetry Reconstruction

For each subject in the **SONICOM** dataset [2], 72 images were captured at 5-degree intervals to achieve a full 360- degree representation.

Apple’s photogrammetry reconstruction **API** produced the most **accurate** and visually **consistent** meshes compared to Agisoft Metashape, AliceVision and Reality Capture.



Each subject mesh obtained from **PR** has a corresponding high-resolution **3D scan** acquired with an EXScan Pro.



Same subject meshes : **[A]** 3D Scan face , **[B]** PR face, **[C]** 3D Scan left ear , **[D]** PR left ear

HRTF synthesis

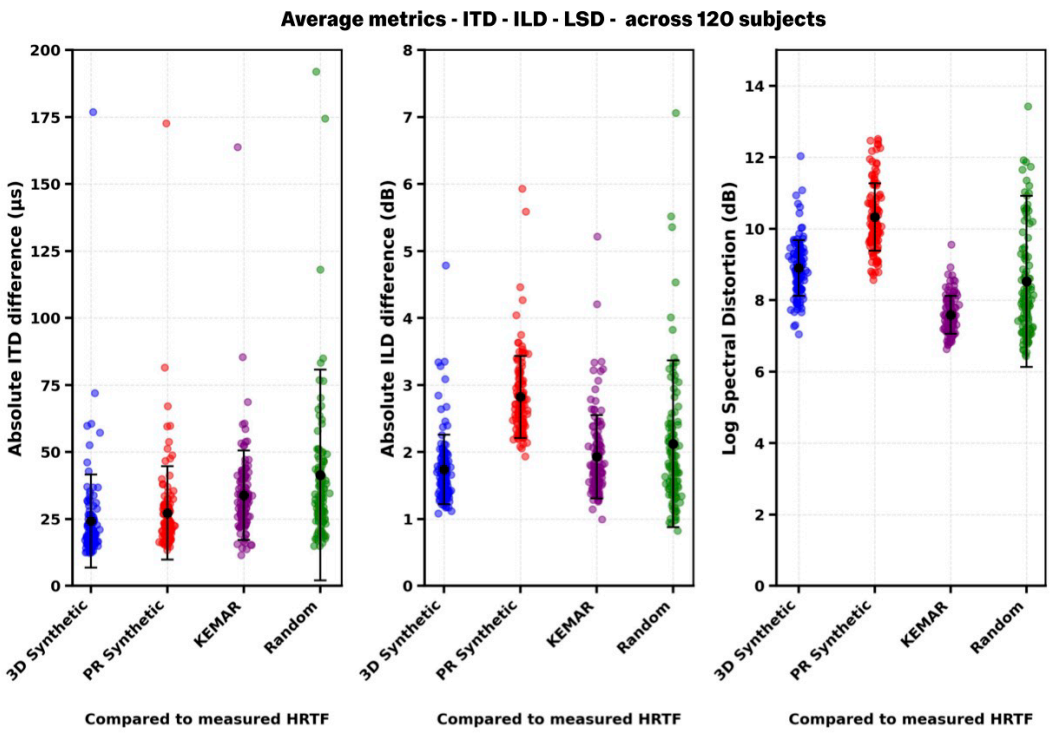
Meshes are processed using **Mesh2HRTF** [3] to generate HRTFs with locations that correspond to the **SONICOM** HRTF measurement setup.

Prior to simulation, **post-processing steps** are applied, including mesh **scaling**, **alignment**, **beheading**, clean-up and curvature-adaptive mesh grading.

Numerical Evaluation (N = 120)

HRTFs synthesised using **photogrammetry reconstructed** meshes are evaluated against **3D synthetic HRTFs**, the **KEMAR** HRTF, **random measured HRTFs** and **measured HRTFs** to establish the **baseline** without the use of a GNN.

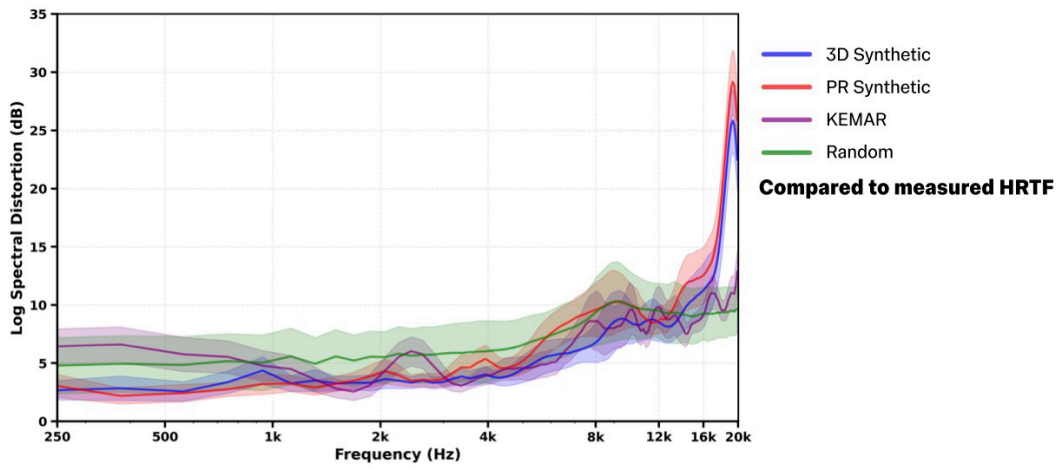
Numerical analysis is performed using the **Spatial Audio Metrics Toolbox** 0.1.2 from Katarina C. Poole, Audio Experience Design Team.



Log spectral distortion (LSD)

PR-derived HRTFs exhibit similar trends to those from high-resolution scans but with **increased degradation**.

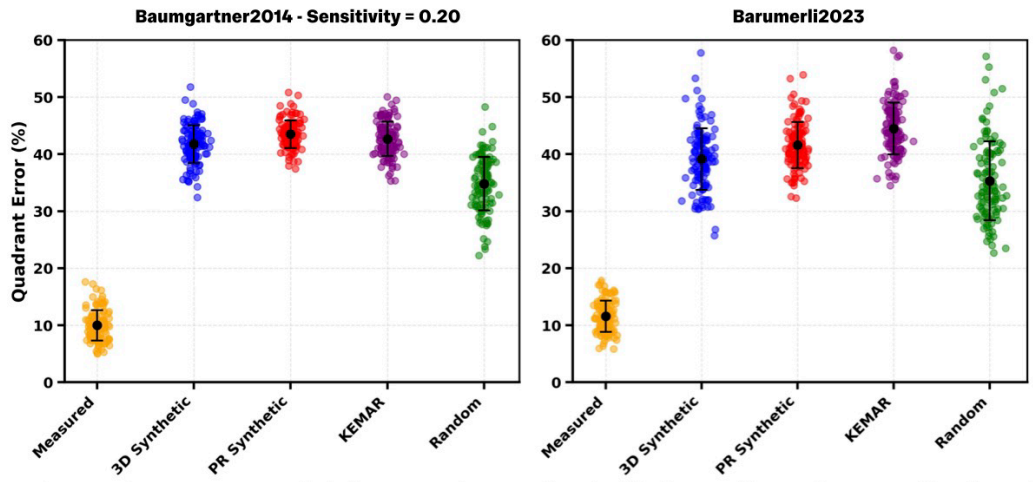
Deviations above **16 kHz** may result from **mesh resolution limits**, **unmodeled materials** and increased sensitivity to anatomical and positioning differences at high frequencies.



Auditory Modelling Toolbox (N = 120)

Baumgartner2014 & Barumerli2023 - Quadrant Error

Template = Measured HRTF for each subject.



The **quadrant error metric** is known to be correlated with the **quality** and **personalisation of pinna spectral cues**.

Conclusion

Photogrammetry Reconstruction quality not only depends on the **data quality** but also on the **algorithm** and software used.

The **numerical evaluation** of PR synthetic HRTFs exhibit **similar trends** to 3D synthetic HRTFs. These results are promising, given that the PR HRTFs are computed **solely from photographs** of the subject.

Spectral distortion above 12 kHz, and higher **quadrant error** rates in auditory model predictions indicate **limitations** in capturing **detailed pinna morphology.**

Perceptual evaluation of PR synthetic HRTFs is currently underway through **localisation tests** and will provide insights into their performance as **individual HRTFs**.

Bio

Ludovic has a background in engineering and artificial intelligence at the **University of Mons, Belgium** 🇧🇪

He enjoys bridging fundamental research with **real-world applications**, from reconstructing **high-resolution 3D head meshes** for acoustic simulations to running **spatial hearing experiments**.

Alongside his academic life, Ludo is also active as a **drum and bass** DJ, blending **Belgian and UK** musical cultures and exploring experimental approaches to **spatial audio in music** 🎶🔊

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AXD

SONICOM HRTF Dataset

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Sustained Interests: Electromagnetically Actuated Feedback Instruments

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Abstract

This work investigates the intersection of science and culture by revisiting the fundamentals of electromagnetics with modern electronics design. Collaborating with practicing musicians and artists has unlocked novel sounds and sonic textures from the same old strings that instruments have been strung with for centuries.

Introduction

Inspired by an expired patent and our ongoing research thread of actuating instrument strings by running electric current them, we have learned how to use a conductive wire as both a sensor and actuator to create co-located and controllable feedback to sustain and augment their vibrations.

Results and Discussion

During our several collaborations, this technology has opened the door to new playing techniques and sounds while being minimally invasive. Our Lorentz Force hardware kit is easily adaptable to different instruments and yields sonically interesting results in many cases. As we continue to augment instruments, we will make engineering improvements to the system as well as consider the affordances of the system and how they can aid in designing new musical instruments, not just existing ones.

Augmented instruments using our hardware: harpsichord (top left), santur (top right), bass drum (bottom left), and autoharp (bottom right)

Core Concept: a conductive wire can act as both a sensor AND actuator

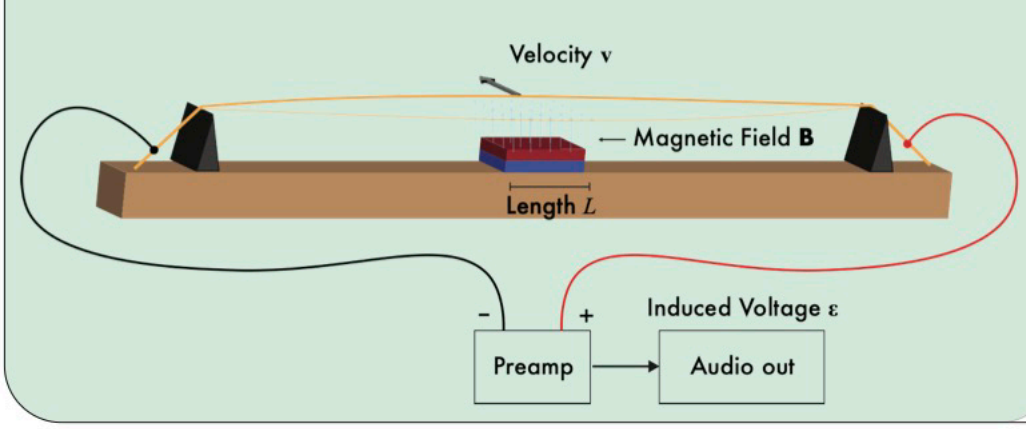
Sensing: Faraday/Lenz's Law

$$\varepsilon = \int (\mathbf{v} \times \mathbf{B}) \cdot d\mathbf{l}$$

ε: induced electromotive force (Volts)
v: velocity perpendicular to magnetic field
B: Magnetic flux density
l: Length of the wire exposed to the magnetic field.

Result: Velocity-induced voltage

Same underlying principle as a dynamic microphone!



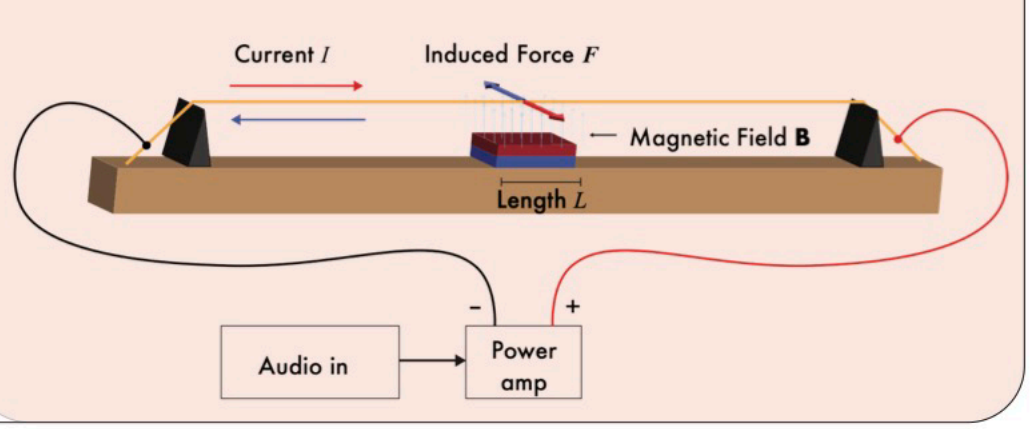
Actuating: Lorentz Force / Laplace Force

$$\mathbf{F} = I\mathbf{L} \times \mathbf{B}$$

F: Force vector felt by wire
I: Current through the wire
B: Magnetic field vector
L: Length of the wire exposed to the magnetic field.

Result: Current-induced force

Same underlying principle as a dynamic speaker!



Methods

1. **Technology Development:** Our custom designed PCBs successfully Time-Division Multiplex (TDM) strings to act as simultaneous sensors and actuators.
2. **Semi-Functional Prototyping:** We put this development in context by actuating and manipulating simple monochords.
3. **Instrument Design:** Guided by our learnings above, we have been deploying the technology into existing musical instruments.
4. **Collaborations:** Our ongoing collaborations provide rich feedback for how to situate this novel technology into musical practice.

Bio

Adam Schmidt is a PhD Student in the Augmented Instruments Lab investigation how the acoustic sounds of instruments can be augmented via electornics.

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Augmented Instruments Laboratory

Marker Information Efficacy: Enhancing Vision-Based Tactile Sensing through Deformation-Aligned Marker Design

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Supervisor: Thrishantha Nanayakkara

Enabling accurate, low-cost, and real-time tactile intelligence for next-generation robotic perception and manipulation

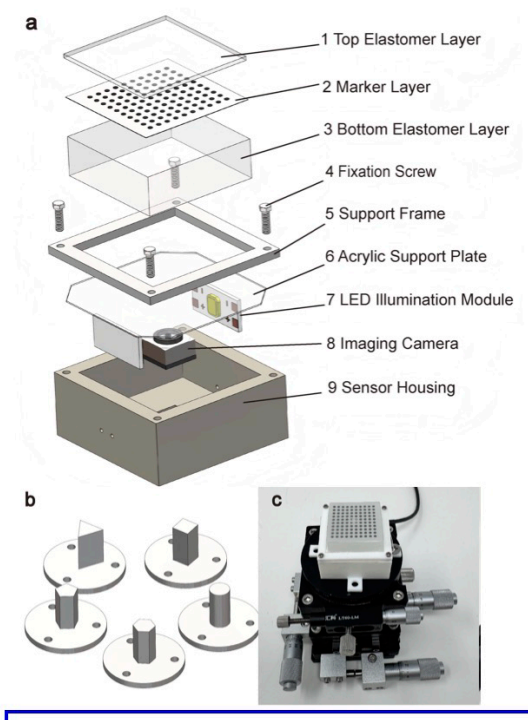
Abstract

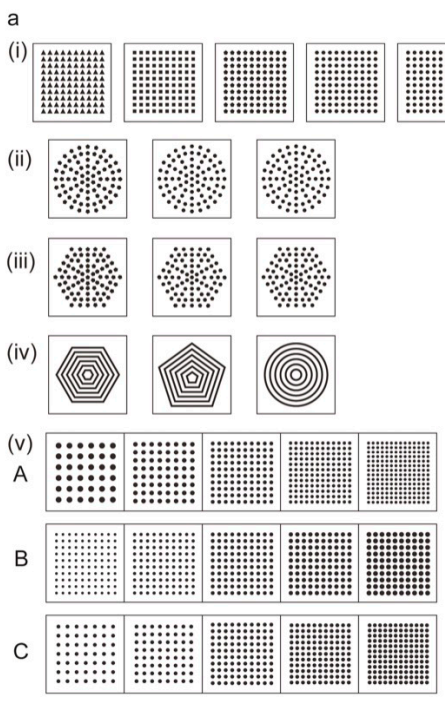
Tactile perception is essential for robotic manipulation, yet the role of marker design in vision-based tactile sensors (VTS) remains underexplored. We propose Marker Information Efficacy (MIE), a design-centric framework that aligns marker geometry and distribution with natural deformation patterns to enhance sensing accuracy and efficiency. Circular markers outperform other geometries, with the concentric-ring design achieving an RMSE of 0.011 N, far surpassing the GelSight benchmark (0.668 N). An optimal density and fill factor of 10–20% enables efficient, real-time tactile sensing.

Introduction

Vision-based tactile sensors (VTS) capture high-resolution deformation of soft interfaces to infer contact forces and geometry, enabling rich spatial perception for robotic manipulation. However, conventional designs treat optical markers as passive tracking points and rarely consider how their geometry, size, or spacing affect deformation encoding. This oversight limits both sensing accuracy and computational efficiency. Marker Information Efficacy (MIE) addresses this gap by introducing a systematic, design-centric framework that aligns marker geometry and distribution with natural deformation patterns, transforming markers into active component of tactile perception.

Methods

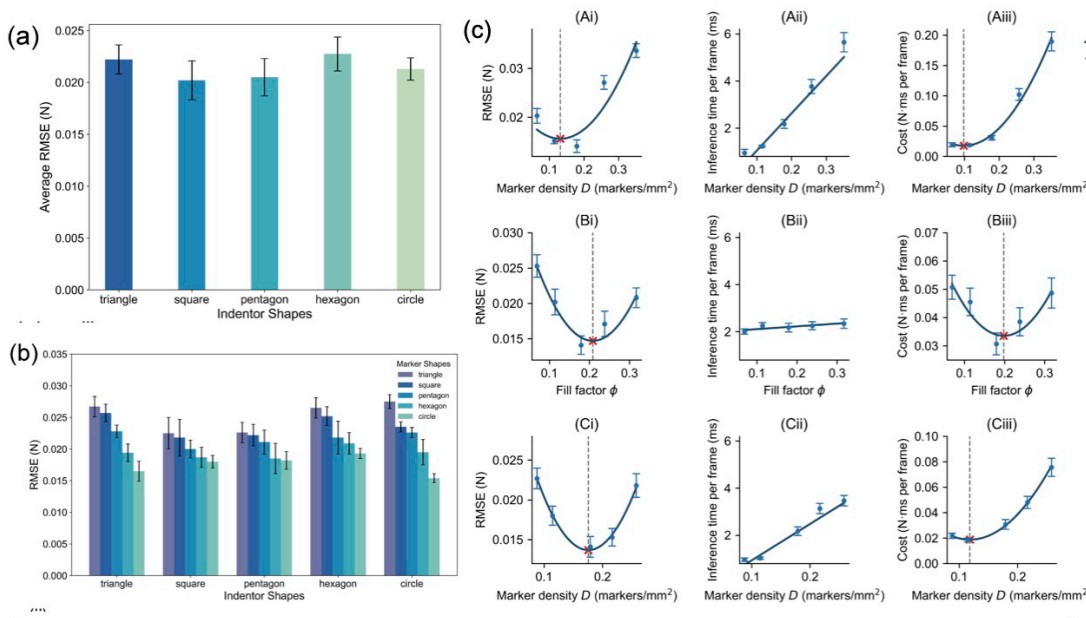




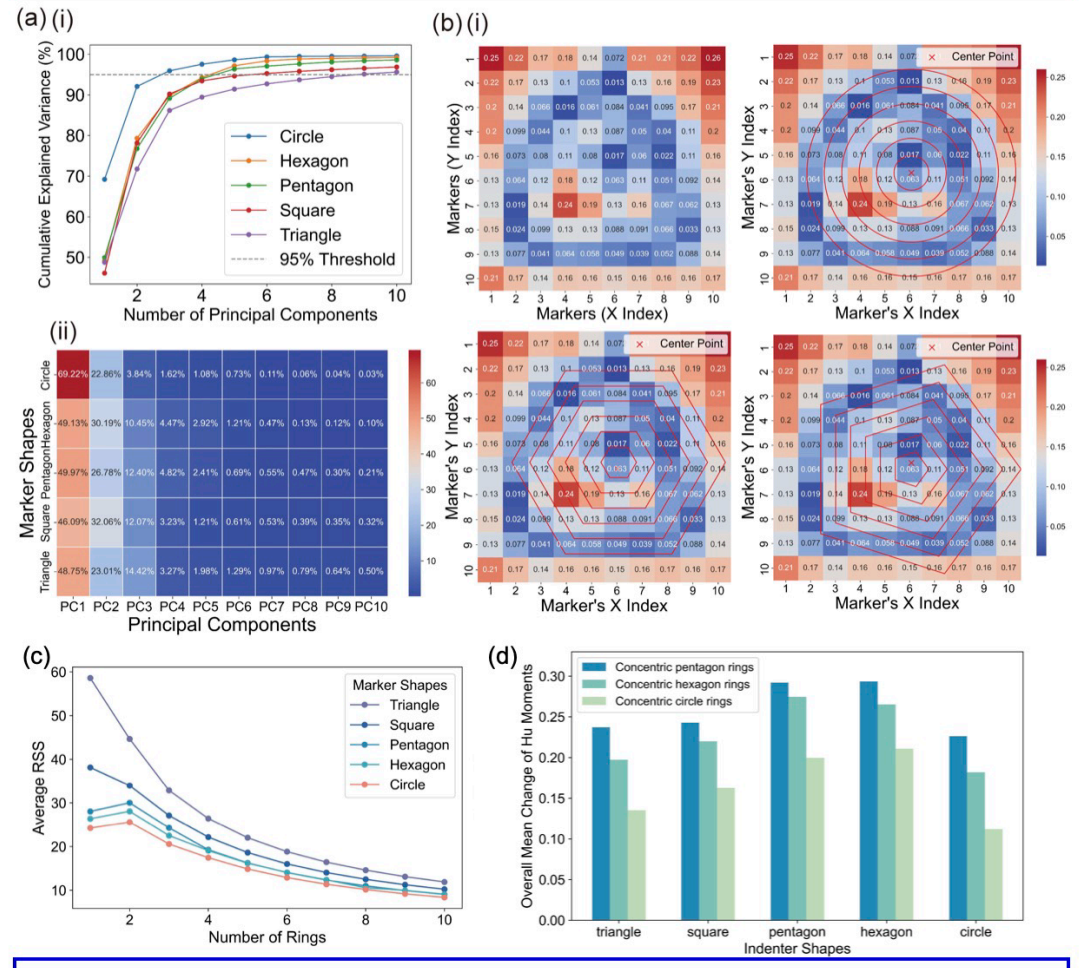
Our vision-based tactile sensor integrates a multilayer elastomer structure and systematically designed marker configurations—spanning distributed, concentric, and density-controlled layouts—to quantify how marker geometry and distribution influence deformation encoding and force estimation.

Results

Circular markers achieve the lowest RMSE across all indenter geometries, demonstrating superior deformation fidelity and tracking stability. A coupled trade-off between marker density and fill factor reveals an optimal range of 10–20%, balancing information capture, robustness, and efficiency.



Principal Component Analysis shows that the first principal component (PC1) dominates deformation representation, indicating that soft-tissue deformation can be effectively described by a single global mode. Residual Sum of Squares fitting confirms that circular rings best approximate this mode, whereas polygonal rings distort the deformation field and cause information loss. Validation further demonstrates that circular concentric-ring markers achieve the highest accuracy and stability, representing the most deformation-aligned configuration.



Circular markers also yield the highest contact-shape classification accuracy, producing more separable and stable deformation patterns than other geometries.

Bio

Tonghui Tang is a PhD student at the Morph Lab, Dyson School of Design Engineering, Imperial College London. His research focuses on vision-based tactile sensing, and embodied intelligence for soft robotic manipulation and real-time haptic perception.

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Learning Network Dismantling without Handcrafted Features

Haozhe Tian, ht721@ic.ac.uk

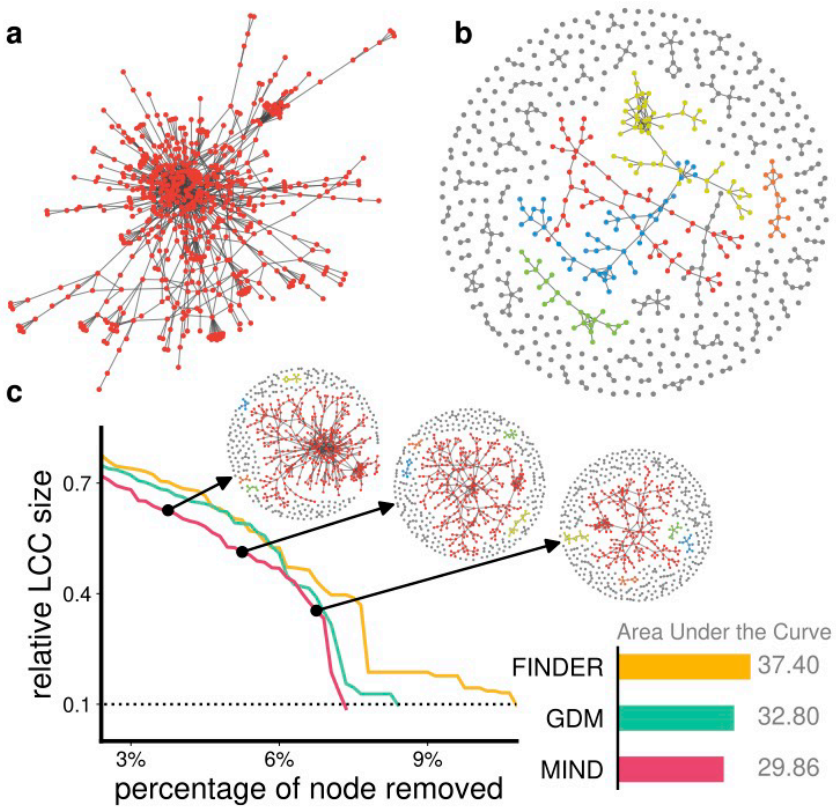
" AI learns to discover the backbone of massive network systems via training on tiny ones. "

The Problem

Imagine the following problems:

- breaking criminal organizations by arresting the key members,
- stopping epidemics with targeted vaccinations,
- ensuring the resilience of healthcare systems via the key providers,

All these problems can be treated as **Network dismantling**, which aims to find the sequence of node removals that most rapidly fragments a network into isolated components.



(**a**) The original social network. (**b**) The network dismantled by MIND. (**c**) Largest Connected Component (LCC) size versus the fraction of nodes removed, comparing MIND with two state-of-the-art methods.

Methodology

For network $G_0 = (V_0, E_0)$, we aim to find a policy π that optimizes:

$$\underset{\pi}{\operatorname{argmin}}\, \mathbb{E}_{v_t \sim \pi(G_t)}\left[\sum_{t=0}^{|V_0|-1} \frac{\mathrm{LCC}(G_0 \setminus \{v_0, \ldots, v_t\})}{|V_0|}\right] = \underset{\pi}{\operatorname{argmax}}\, \mathbb{E}\left[\sum_{t=0}^{|V_0|-1} r_t\right],$$

where $r_t = -\frac{\mathrm{LCC}(G_t \setminus \{v_t\})}{|V_0|}$. This is a sequential decision-making problem that can be solved by Reinforcement Learning:

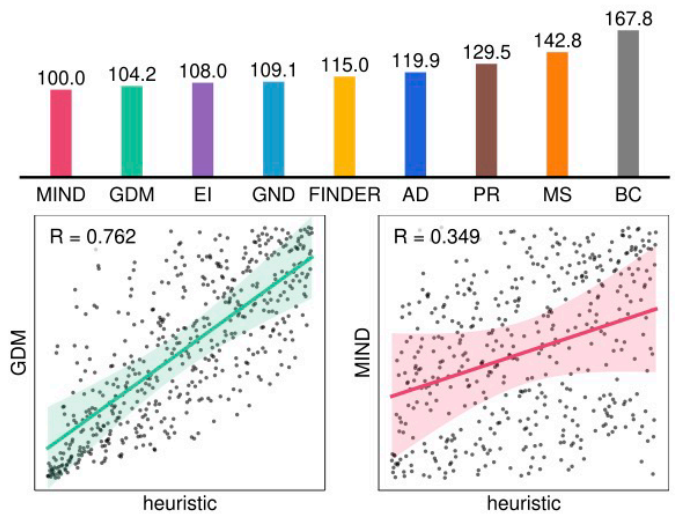
$$Q(G_t, v_t) = r_t + \mathbb{E}\left[\sum_{k=t+1}^{|V_0|-1} r_k\right] = \mathbb{E}_{samples}[r_t + Q(G_{t+1}, v_{t+1})]$$

$$\pi^*(G_t) = \underset{v_t}{\operatorname{argmax}}\, Q(G_t, v_t)$$

The $Q(G_t, v_t)$ uses an encoder-decoder structure. In the encoder, we propose a novel GNN structure where each node v_i is initialized with embedding $e_i = \mathbf{1}$ and iteratively updated using attention-based message-passing. In the decoder, all the node embedding from the message-passing iterations are mapped into the Q-function values $Q(G_t, v_i) = \mathrm{MLP}(e_i)$. The localized message-passing operator allows generalization from small networks to large networks.

Results and Discussion

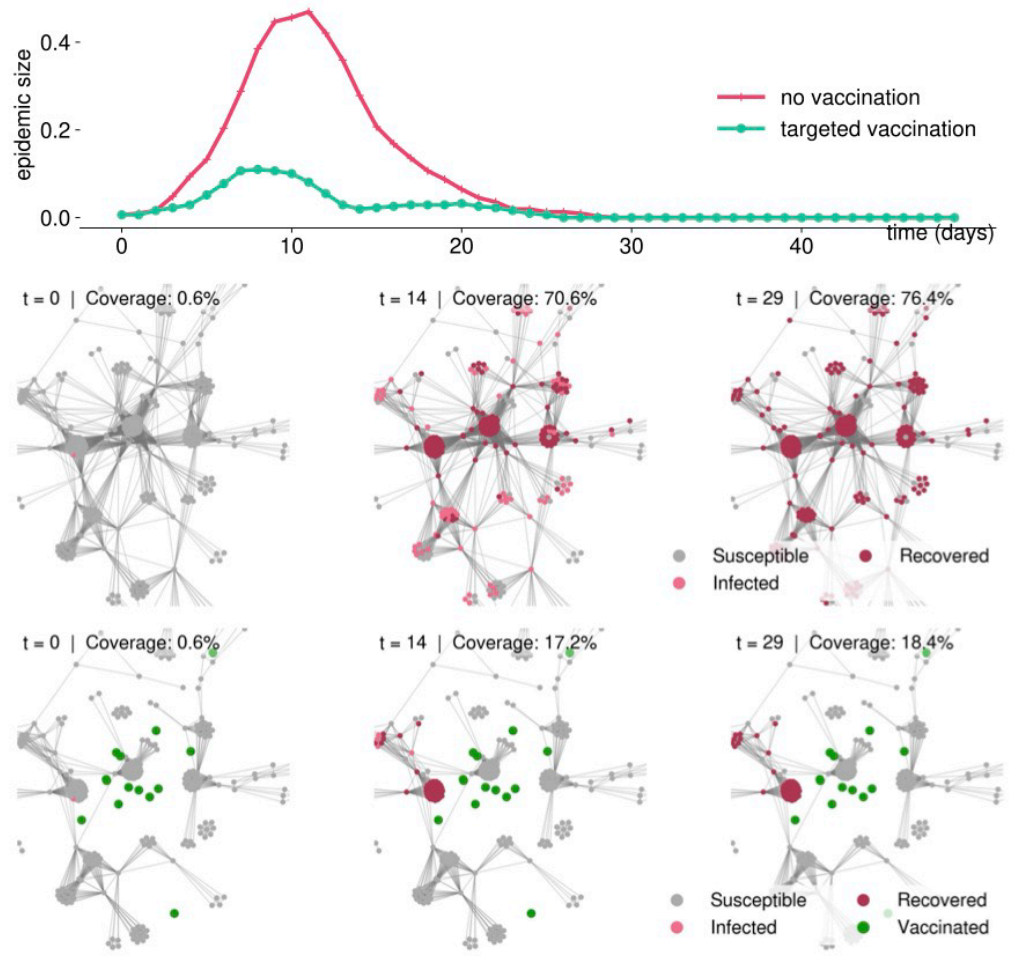
MIND can be efficiently trained on tiny networks while generalizing to real networks with million of nodes. The SoTA performance of MIND stems from its purely geometric learning framework **without input heuristics**, whereas most GNN frameworks rely on heuristic node initialization that is i) computationally expensive and ii) specific to certain type of networks.



Overall performance on 48 real networks. We compare the node dismantling sequence derived (by PCA) from a set of heuristics with those generated by GDM and MIND. The heuristic removal sequence is derived from the principal component of GDM's input node features. We observe that GDM removes nodes with similar order as given by the combination of its heuristic input features (is biased by them), but MIND removals are uncorrelated with the heuristic ranking.

Application

We show that the dismantling solution generated by MIND leads to an effective targeted vaccination strategy. We simulate the spread of disease using the Susceptible Infected Recovered (SIR) model. Let ρ be the number of initially infected people, β denote the transmission rate, and γ is the recovery rate. At each step, the susceptible node v_i becomes infected with probability $p = 1 - (1 - \beta)^n$, where β is the infection probability and n is the number of infected neighbours of v_i. An infected node recovers after γ timesteps and won't catch the disease again afterwards.



Simulation result using the SIR model, with 2 initial patients, infection rate 4%, and recovery time 7 days. After targeted vaccination, disease is contained in a small fraction of the overall population.

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MODELLING PERCEIVED AUDIO QUALITY IN HEARING AIDS USING PAIRWISE COMPARISONS

Jack Webb[1], Christophe Lesimple[2], Volker Kuehnel[2], Lorenzo Picinali[1]

[1] Dyson School of Design Engineering, Imperial College London, UK
[2] Sonova AG, Stäfa, Switzerland

Introduction

Hearing aids have been primarily optimised for **speech signals** and often degrade **music quality**, leading to difficulties hearing **individual instruments** or **lyrics** [1]. Effective computational models of perceived sound quality are needed to find engineering solutions to these limitations.

Existing quality models may overlook two critical factors in perceived sound quality: the role of **spatial image**, and **listener-specific preferences** that are hidden when models are fitted to averaged opinion scores, an approach known to be statistically fragile [2].

To address this, we propose a fast **pairwise comparison** method for more robust perceptual data collection, and validate it in an online listening test examining how **spatial image** affects music quality in hearing aids.

Methods

Proposed Algorithm

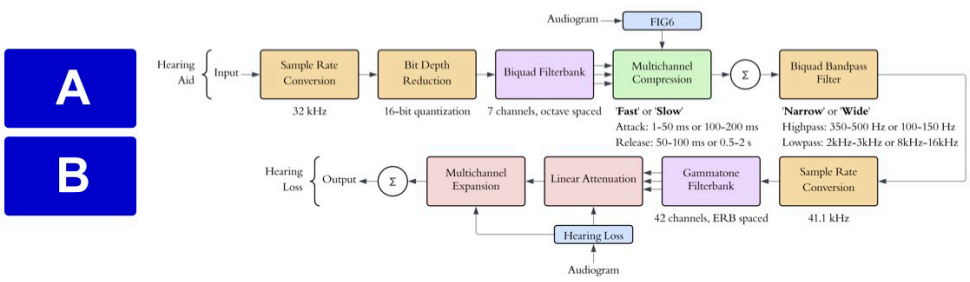
Sort-MST tracks stimulus ratings using Elo scores and predicts the most informative next comparisons by forming a minimum spanning tree. This reduces the number of trials necessary to approximate accurate quality ratings.

Monte Carlo Simulation

Simulated perceptual rating tests compare Sort-MST with five alternative procedures, assessing **convergence** under varying observer **uncertainty**.

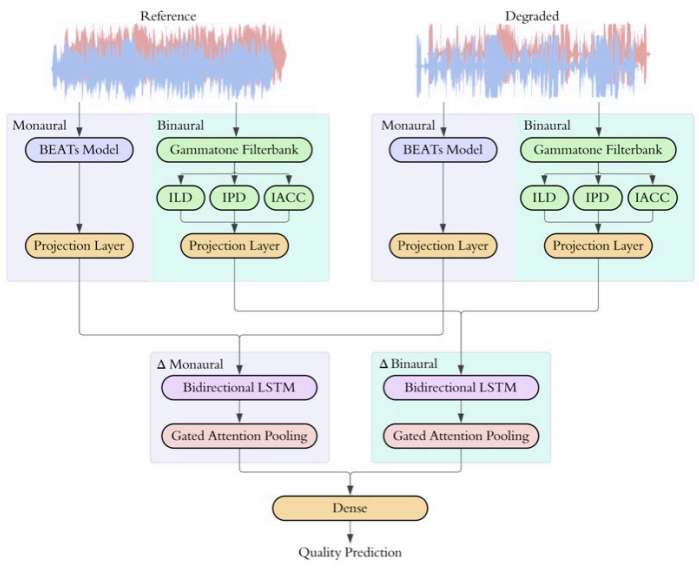
Online Listening Test

Participants (N=7) perform pairwise comparisons organised by Sort-MST between signals processed through a **hearing aid** and **hearing loss simulator**.



Prototype Quality Model

Ratings from the listening test are used to train a new perceptual quality model. The model combines **binaural** and **monaural** features in a **neural network** to capture both spectro-temporal and spatial degradations.

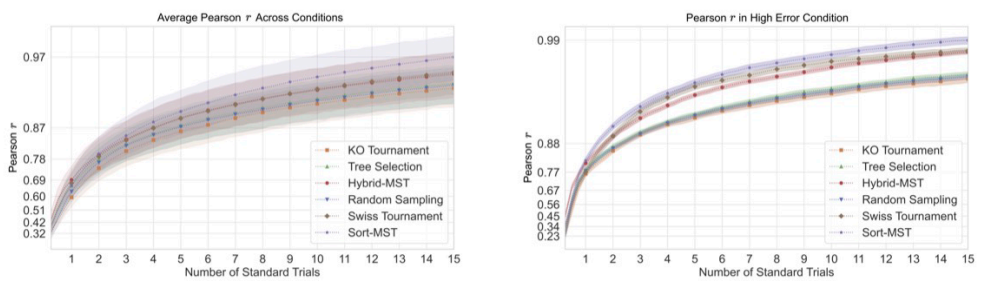


"Pairwise comparisons provide an **efficient** way to capture **perceptual ratings** for training **complex computational models."**

Results

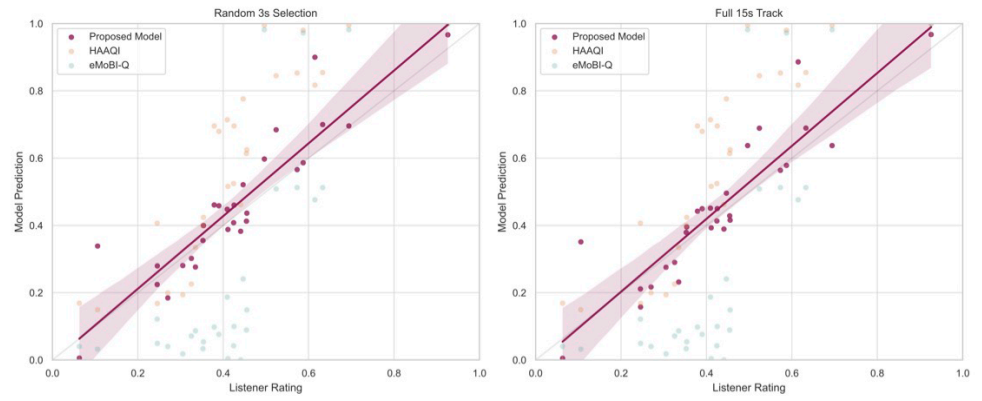
Monte Carlo Simulation

On average, Sort-MST achieves correlations **comparable** or **superior** to optimal **Bayesian** algorithms with **lower computational cost**, and remains **robust** under high observer **uncertainty** and **error**.



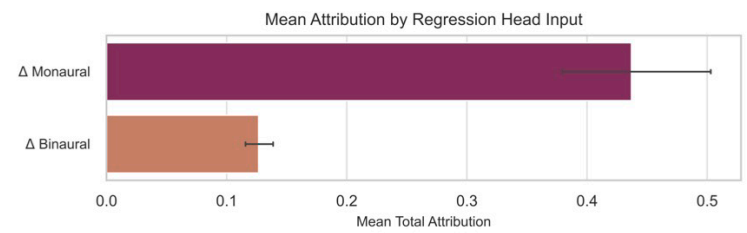
Listening Test & Prototype Quality Model

On a 20% test split of hearing aid signal-rating pairs, the prototype model shows **improved correlations** over two existing models: **HAAQI** [3] and **eMoBi-Q** [4].



	Prototype Model	HAAQI	eMoBi-Q
3s Pearson r	**0.9141**	0.8606	0.7715
15s Pearson r	**0.9044**	0.8606	0.7715

Applying **Integrated Gradients** analysis to the regression head of the predictive model reveals that **monaural** degradations **dominate** perceived quality, though **binaural** degradations affecting **spatial image** also have a **notable role**.



Discussion & Conclusion

The strong performance of the prototype model suggests two key findings. First, **pairwise comparisons** can efficiently capture **subjective ratings** for fitting **improved computational models** of auditory percepts. Second, **music quality** in hearing aids likely includes a **binaural component** overlooked by current metrics.

Binaural cues have received limited attention in hearing aid audio quality assessment. These results offer preliminary evidence that future hearing aid algorithms may benefit from optimising sound quality **bilaterally**, taking account of spatial distortions to **enhance music listening** experiences.

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sonova HEAR THE WORLD

A Continuum-Scale Model for Nickel-Rich Cathode Degradation in Lithium-ion Batteries

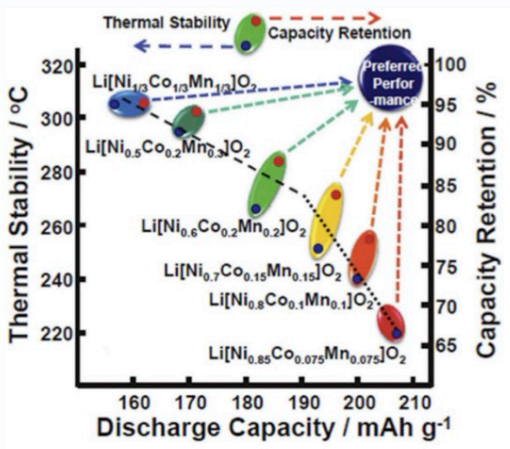
A novel physics model to unlock durable, high-energy density lithium-ion batteries

Toshan Wickramanayake (t.wickramanayake@imperial.ac.uk), Gregory Offer, Billy Wu

Abstract

- **Motivation** - Nickel (Ni)-rich lithium-ion batteries (LIBs) offer higher energy density and extended driving range for electric vehicles (EVs) but suffer from degradation that limits long-term performance [1,2].
- **Focus -** Examines the oxygen evolution reaction (OER) as a key degradation pathway causing solvent oxidation and capacity loss in Ni-rich LIBs [1,2].
- **Research Gap -** Despite extensive experiments, no validated cell-level model for OER degradation exists.
- **Methodology –** Introduces a novel "shrinking-core" framework where Ni-rich particles have an active core and an inactive shell. OER kinetics are described using a Butler–Volmer relationship [3].
- **Outcome –** Model validation shows good agreement with experimental oxygen release data and reproduces the self-limiting degradation behaviour observed experimentally.

Background on Ni-Rich LIBs

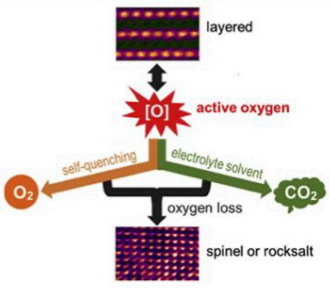


Increasing Ni content in LIB cathodes leads to:

- Reduction in cobalt content in LIBs.
- Increase in specific energy density.
- Reduced capacity retention.

One cause of reduced capacity retention is **solvent oxidation** in the LIB [4].

Oxygen Release and Solvent Oxidation



Oxygen Evolution Reactions (OER) in Ni-rich Cathodes:

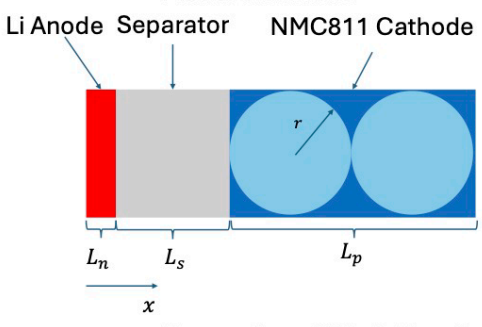
$$Li_yMO_2 \leftrightarrow Li_{yMO} + O$$

Solvent Oxidation at Cathode/Electrolyte Interface:

$$Solvent + O \rightarrow CO + CO_2 + CEI + H_2O$$

The Shrinking Core Model

Model Structure



Model Variables

c_s - Lithium concentration in 'core' phase
c_o - Oxygen concentration in 'shell' phase
s – Core/Shell Boundary Location
j_{int} - Lithium intercalation molecular flux
$\frac{\delta s}{\delta t}$ - Rate of core/shell boundary movement

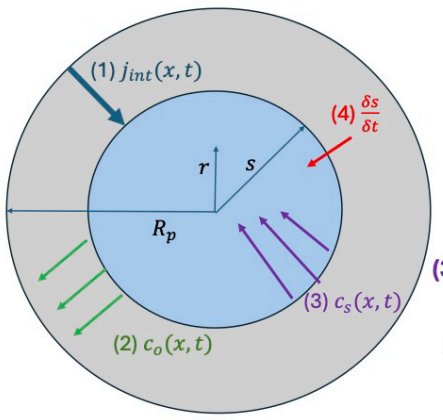
Illustration of 'Shrinking Core' Physics in an NMC811 Particle

(1) Lithium intercalation reactions:

$$j_{int}(x,t) = \frac{i_o(x,t)}{F} sinh\left(\frac{F}{2RT(x,t)}\eta(x,t)\right)$$

(4) Oxygen Evolution Reaction:

$$\frac{\delta s}{\delta t} = -k_1[c_s(x,s,t)^{\alpha_{sh}}/c_{thrd}]\sinh(\tfrac{F}{2RT}\eta(x,t))$$



(2) Oxygen Diffusion:

$$\frac{\partial c_o(x,r,t)}{\partial t} = \frac{D_o^{eff}}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial c_o}{\partial r}\right)$$

$$-D_o^{eff}\left.\frac{\partial c_o(x,r,t)}{\partial r}\right|_{r=s} = \frac{\delta s}{\delta t}(c_o(x,s,t) - c_{oc})$$

$$c_o(x,R_p,t) = 0$$

(3) Lithium Diffusion:

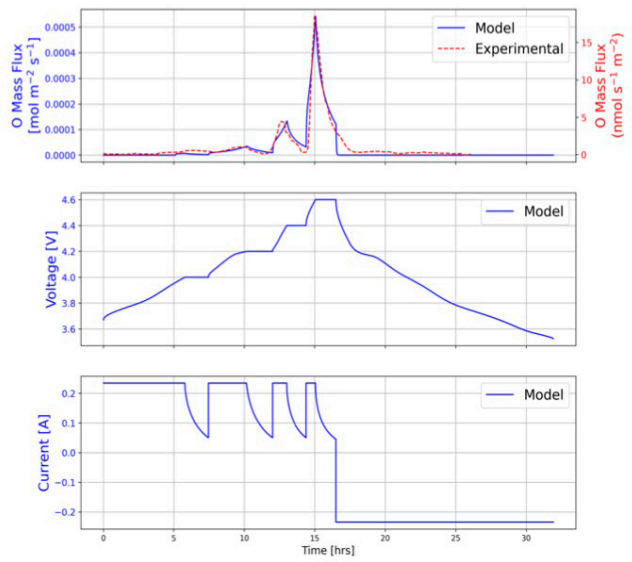
$$\frac{\partial c_s(x,r,t)}{\partial t} = \frac{D_s^{eff}}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial c_s}{\partial r}\right)$$

$$-D_{s,p}^{eff}\left.\frac{\partial c_s(x,r,t)}{\partial r}\right|_{r=s} = (R/s)^2 j_{int}(x,t) - \frac{\delta s}{\delta t}(c_s(x,s,t) - c_{s,sh})$$

$$\left.\frac{\partial c_s(x,r,t)}{\partial t}\right|_{r=0} = 0$$

Model Performance

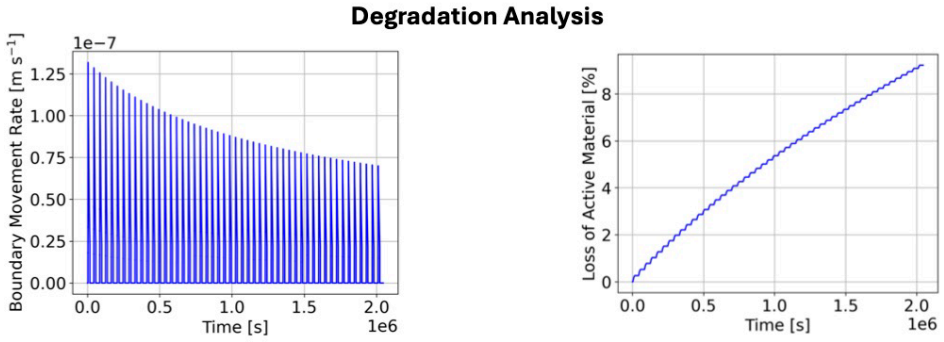
Initial Model Validation



To verify model performance, we used mass spectrometry data from Thornton et al [2]. Key points:

- We replicated their experiments with this model – a charge/discharge experiment, with charge holds at 4V, 4.2V, 4.4V and 4.6V.
- We compared the oxygen mass flux rates with the model to experiments (top plot).
- The oxygen release behaviour generally follows that seen in experiments.

Degradation Analysis



To further verify model performance, we simulated the model for 50 charge/discharge cycles. Key points –

- The rate of degradation reduces with each cycle (left figure) – self limiting behaviour.
- The loss of active material follows a 'square root of time' behaviour (right figure) – This has also been experimentally reported [1].

Conclusions

In this work, a novel continuum scale physics model is presented, to capture the OER process in Ni-rich LIBs. Key findings:

- The model proposes a 'Shrinking-core' framework to model the oxygen release process in Ni-rich LIBs.
- Initial model validation shows good agreement for oxygen release, compared to experimental data [2].
- Long-term cycling performance shows the OER degradation process is self-limiting, as also reported in experimental work [1].

Future Work

To further improve this work, the following research will be caried out:

- The OER reaction mechanism (see Equation (4)), is currently empirically derived. While this gives good model agreement, the exact form of this equation needs to be derived from first principles.
- Currently, the model only captures the OER process. The model has to be extended to capture solvent oxidation.

Researcher Bio

Tosh Wickramanayake is a research assistant in lithium-ion battery modelling at the Dyson School of Design Engineering. He is a part of the multi-scale modelling project, by the Faraday Institution. Tosh followed a PhD in Electronic Engineering from Queen Mary University of London. He also has an MSc from the University of Surrey and an MEng from the University of Cambridge. He is also one of the current postdoc representatives at the Dyson School of Design Engineering.

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THE FARADAY INSTITUTION MULTI-SCALE MODELLING Modelling

Development of an automated trans-tibial prosthetic socket design pipeline

Eddie Yang, e.yang24@imperial.ac.uk
Dr Connor Myant

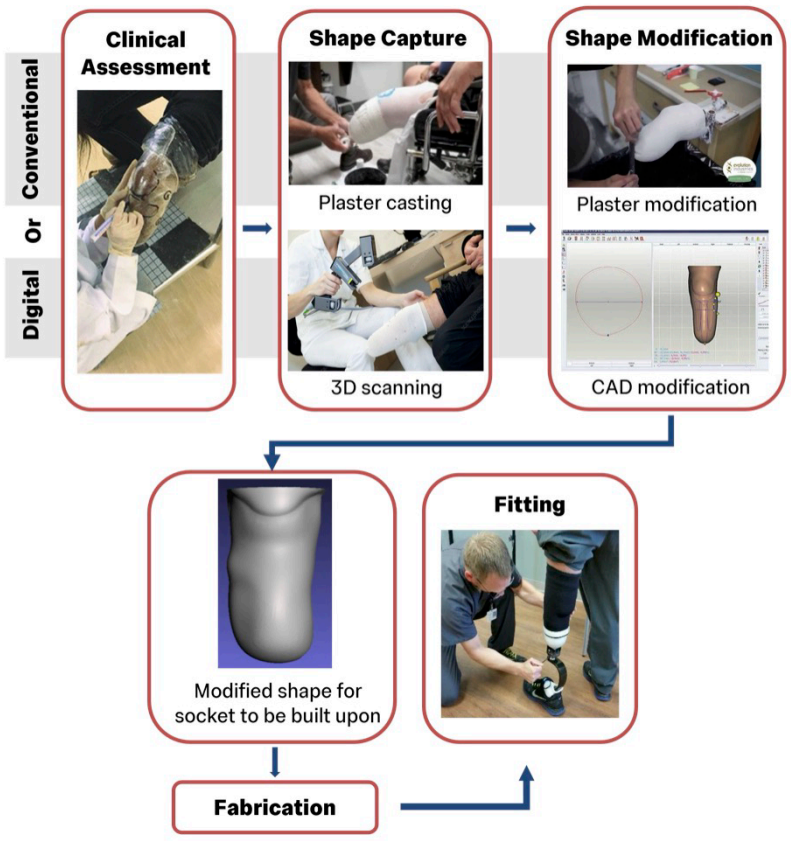
> "**Transcoding** the craft-based design skills of a prosthetist to **automate** digital socket design"

Introduction

Current methods of designing a trans-tibial prosthetic socket relies on the subjective, craft-based skills of the prosthetist. This method is labour intensive and is not scalable to address the growing amputee population's needs, where WHO estimated that only 10% of amputees globally have adequate access to the necessary prosthetic intervention they require.

Digitalisation of socket production is often suggested for scalability of services. Although a digital workflow exists in clinic practice, current software are designed to replicate the conventional practice in a virtual form, but lack the hands-on approach that prosthetists are familiar with during socket design. Hence, digital uptake in clinics are low and further limits the potential for scalability.

Current Clinical Workflow for Socket Production



The aim of the research is to explore the development of a prosthetist-driven digital socket design tool that integrates well with existing clinical practices, enabling the prosthetist to operate it in an intuitive manner, while facilitating automation of transtibial prosthetic socket design.

Limb Mimics for Pipeline Evaluation

To aid in the development of the prosthetist-driven automated socket design tool, iterative evaluations on residual limbs are required. To ensure accessibility and repeatability of tests throughout the development process, limb mimics of consistent internal and surface geometry and volume are created to serve as evaluation tools. The mimics would offer sufficient anatomical realism and provides the tactile feedback prosthetists would expect to receive during the assessment of a patient's residual limb.

(a) MRI images of residual limbs were segmented in 3D Slicer
(b) Moulds of internal anatomical structures were created through stereolithography (SLA) 3D printing and casted in silicone.
(c) Completed limb mimic with skin encapsulating internal structures

Prosthetist-driven Automated Pipeline Design

The research hypothesises that prosthetists will be able to embed shape modification information directly onto the residual limb during the shape capture stage, which can be interpreted by a software, performing automated modifications.

In clinical practice, prosthetists already annotate positions of anatomical landmarks on residual limbs when assessing the patient. By adapting this practice, the pipeline approach suggests prosthetists to:
(a) place additional coloured markings which predicts the location of shape modifications required for the socket, utilising the hands-on approach that is intuitive
(b) 3D scanners that already used in clinic by prosthetists, allow for the capture of rich, texture and geometric information. A 3D scan of the limb imports the limb's geometry along with colour markings into the digital space.
(c) Software that is custom designed to interpret coloured information can then be used to automatically extract certain regions from the limb model and apply shape modifications to them

Clinician Focus Group Findings

- Current digital software used by prosthetists are still not well-integrated into clinical practice
- Current software only utilises surface geometry and requires the prosthetist to use mainly visual information for socket design as they lack the physical-based feedback they are familiar with, limiting their effectiveness
- The prosthetist-driven pipeline encodes physical-based information, and translates it into a digital form which allows prosthetists to "design the socket directly on the limb" while harnessing the efficiency of digital automation
- However, prosthetists commented that the pipeline would require a mindset shift to plan for socket design and modifications right from the patient assessment stage

Further Work

- Use of limb mimics to investigate the accuracy and repeatability of prosthetist palpation for anatomical landmarks
- Investigate quantification of hands-on approaches used during socket design
- Incorporating quantified information into an algorithm for prosthetist-driven automated socket design

Bio

Eddie is a PhD student at the Advanced Manufacturing Group, supervised by Dr Connor Myant. Prior to the PhD, he was a practising prosthetist and orthotist.

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Behaviour Setting-Driven Extended Reality: Framework, Tool, and Guidelines

Xiaoyang Zhao, Dr. Weston Baxter, Prof. Sebastian Deterding, Dr. Porat Talya, Prof. Robert Aunger

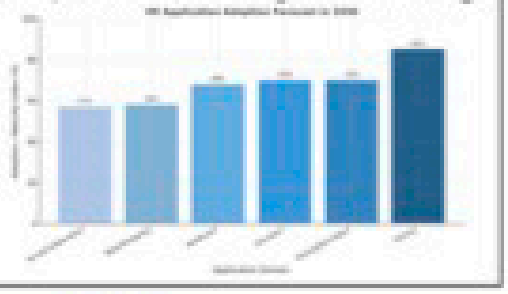
Background & Motivation

Background:

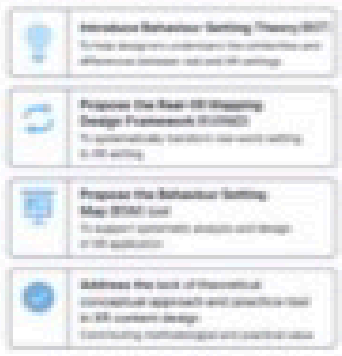
- Extended Reality(XR) is widely used in applications in entertainment, education, training, and shopping. It is transforming lives, businesses and society at large.
- XR, including Virtual Reality (VR) and Augmented Reality (AR) and Mixed Reality (MR), is often reconstructed around users' real-world expectations to varying degrees in order to enhance immersion.

Motivation:

- There is no systematic and standardised approach to understand, map and transform complex real-world settings into XR settings.



Objectives

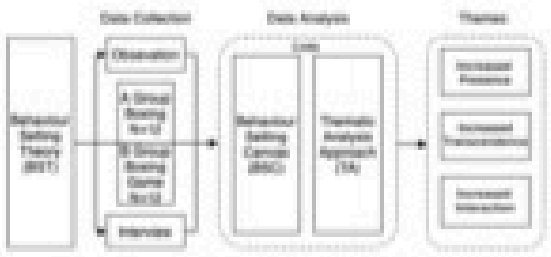


- **Introduce Behaviour Setting Theory (BST)** to clarify the conceptual parallels and distinctions between real and XR settings.
- **Propose the PIT Framework** for systematic transformation from real-world to XR settings.
- **Develop the Behaviour Setting Map (BSM) as a practical tool** for structured XR content analysis and design.
- **Address the gap in theory and tools for XR content design**, contributing both methodological insight and practical utility.

Method

Study 1: Understand Real Settings

- **Snowballing literature review method**
- **Comparative study:** Conducted **interviews** with VR, AR and MR participants **(N=24)**
- **Thematic analysis** was used for data analysis, combining both inductive and deductive reasoning.



Study 2: Transform Real into XR settings

Aim:

- Exploring opportunities and challenges in XR design phase
- Developing and evaluating XR design tool
- **Formative study:** evaluated Behaviour Setting Canvas(BSC) with designers **(N=30)**

- **Behaviour Setting Map (BSM) Development Collaborative workshop:** based on findings, the BSM tool was developed and evaluated through a collaborative workshop with designers **(N=24, Average age SD=1.40)**

Evaluation:

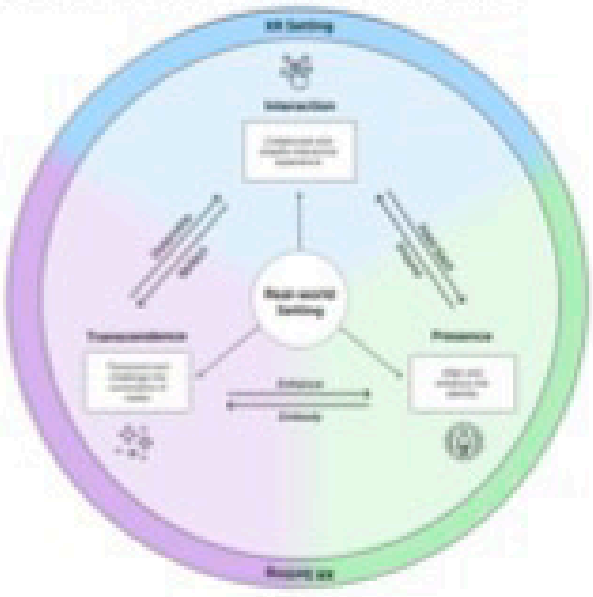
1. Subjective satisfaction survey assessing their experience with the overall BSM and its individual modules
2. Questionnaire measuring Perceived Usefulness (PU) and Perceived Ease of Use (PEU) of BSM; and
3. Semi-structured focus group interview was conducted.

Results

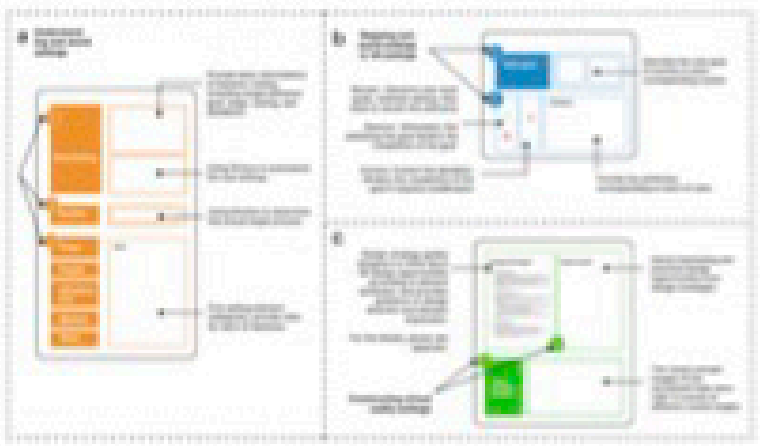
Result 1: The Real-XR Mapping Design Presence, Interaction and Transcendence (PIT) Framework

- The **PIT framework** shows how real settings translate to virtual settings based on three key dimensions: **Presence, Interaction, and Transcendence**. These three dimensions are interrelated and collectively contribute to the creation of a situated interactive experience. Notably, these dimensions are interconnected within the XR setting, and also linked back to the original setting elements.

Transitional Dimension	Description
Presence	serves as the foundation for human-environmental synomorphy (interaction), and can be further enhanced through the involvement of fantasy
Interaction	is manifested through avatars and virtual objects, while also reflecting the operational mechanisms of fantasy
Transcendence	determines how interaction is orchestrated, and are ultimately expressed through presence as their experiential vehicle.



Result 2: Behaviour Setting Map (BSM)



- **BSM** is structured into three main modules: Understanding real-world settings,Mapping real-world settings to XR settings, and Constructing XR settings. BSM evolved and expanded from the PIT framework and the BSC.
- This modular structure is expected to clearly communicate to designers the process and strategies for transitioning from understanding real-world settings to mapping and designing XR ones.

Subjective satisfaction: The scale demonstrated good internal consistency **(Cronbach's α = 0.852)**.These results suggest that BSM performs well as a contextual analysis tool and highlights its positive impact in supporting designers as they map real-world settings to virtual settings and create XR design content.

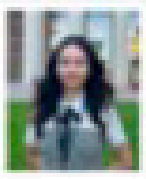
Perceived Usefulness (PU) of BSM: These findings suggest that the BSM tool holds strong potential for helping participants save design time, improve efficiency, and enhance task completion in the early stages of XR development.

Perceived Ease of Use (PEU) of BSM: These findings reflect a generally positive perception of BSM's PEU, while also pointing to opportunities for enhancing interaction smoothness and reducing the learning curve.

Future Work

- Improve Evaluation Design: Adopt multi-stage or longitudinal assessments to better reflect user experience and usability.
- Assess Prototype Quality: Conduct expert reviews and comparative studies to evaluate BSM's effectiveness in producing high-quality XR applications.
- Support Full Development Workflow: Extend BSM's utility beyond early prototyping to include later phases like interaction programming.
- Agentic BSM with Generative AI. Develop an agentic BSM that leverages large language and text-to-image models to automate the end-to-end XR design workflow.

Bio



Xiaoyang Zhao is a PhD student at the Dyson School of Design Engineering at Imperial College London.Her research focuses on Extended Reality (XR) design, user experience in XR, behavior change design, human-computer interaction, gamification, and spatial embodied intelligence.

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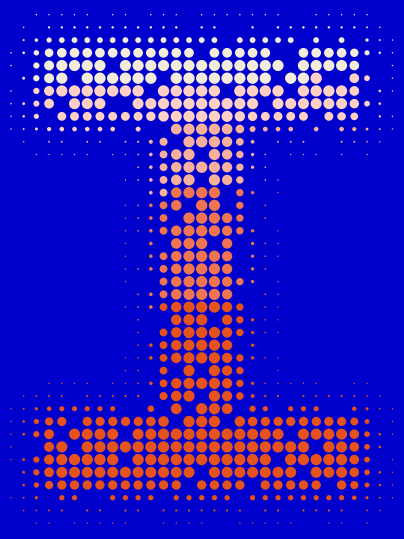

Poster Symposium Oct 2025

DESIGN: Mingke Wang

EDITOR: Mazdak Ghajari