Designing Sound Interactions in Spaces

a Sound-Based framework for architectural interiors' repurposing and development

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Abstract

This research investigates the aural dimension of public interiors as an active and interactive component of spatial experience, rather than a purely technical issue limited to sound insulation or absorption. Sound is addressed as an intangible, relational, and temporal material that mediates interactions between space, human presence, and non-human agents, including architectural elements and environmental dynamics. Through an interdisciplinary framework bridging design, *Sound Art*, and acoustics the project explores how sonic phenomena can foster responsive and participatory environments. By framing sound as a system capable not only of responding to and influencing its context, but as a primary design material to be considered "a priori", the research proposes the development of sound-informed spatial design guidelines to inform future practice, aiming to enhance comfort, awareness and engagement in public interiors.

CCS Concepts

• **Applied computing** → Arts and humanities; Sound and music computing; Arts and humanities; Media arts; Arts and humanities; Architecture (buildings); • **Human-centered computing** → Interaction design; Interaction design theory, concepts and paradigms; • **General and reference** → Document types; General literature.

Keywords

Spatial Design, Sound Driven Design, Sonic Interaction Design, Sound Art, public interiors

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Extended abstract

Contemporary spatial experience has undergone profound transformations, particularly within the perceptual and emotional dimensions of experience, here identified as the ongoing active and alert interaction between human beings, environments, and spaces [11]. This shift foregrounds not merely the tangible attributes of architectural environments, but equally the perceptual dimensions that generate emotional resonance within artefacts [22]. Reconceptualising spatial perception necessitates transcending the visual-centric bias that has historically characterised Western architectural thought [29], moving instead towards multisensory design frameworks [7]. The auditory dimension emerges as particularly significant within this expanded sensory palette: sonic phenomena and their interrelationship with constructed and natural environments fundamentally shape our navigational strategies and spatial utilisation patterns, thereby influencing cultural practices and social conventions [12]. Furthermore, acoustic conditions modulate our subjective experience of security [27] and serenity [24], whilst more broadly determining qualities of comfort, intimacy, and opportunities for collective narrative attributes of considerable importance in both urban and architectural public environments.

Within accessible interior environments, acoustic management presents considerable complexity owing to the possible multiplicity of concurrent interactions. The acoustic wellbeing of an interior space constitutes an essential component of Indoor Environmental Quality (IEQ) parameters [17]; considerations in this regard must take into account the complex relationships between the constructive characteristics of the environment, the activities that take place within it, and the perceptual expectations of its users. Ensuring comprehensible verbal communication and appropriate acoustic privacy frequently demands the incorporation of sound-isolating panels, sound-absorbing furniture, or comparable acoustic interventions [20]. Nevertheless, the acoustic dimension need not be conceptualised solely as a constraint requiring mitigation; rather, it may be actively orchestrated as a malleable design material. Approaching sound as a concrete, sculptable element enables designers to craft interior *soundscapes* [28] that fulfil both functional imperatives and aesthetic ambitions. Whilst the soundscape concept is primarily approached from the perspective of open spaces, the term has been progressively applied to enclosed built environments as well [15]; indoor soundscapes, however, remain an underdeveloped area of research, still lacking consolidated theoretical and methodological frameworks [16, 30]. Nonetheless, this perspective shifts focus from merely suppressing undesirable acoustic phenomena towards cultivating novel spatial experiences that can be informed by contemporary sonic experimentation and technological intervention.

From the second half of the 20th century onwards, new electroacoustic composition practices have explored not only the domain of time, but also that of space [25], delineating the emergence of sound installations and sculptures that can be ascribed to the artistic



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macro-genre *Sound Art* [19]. *Sound Art* installations and sculptures' value derives from experiencing their *hic et nunc* – the here and now – namely the active fruition and/or participation of the audience within the exhibition, therefore fully enjoying the "Aura" defined by Benjamin [5] as the intangible authenticity of an artwork derived from experiencing it directly in its designated place, which cannot be reproduced elsewhere or at another time. *Sound Art* works largely benefit from the technical possibilities provided by sound recording and reproduction technologies, without which almost no work of this macro-genre could exist. This technological mediation and the disappearance of the performer, making the work seem to live autonomously, are essential to defining the genre. Furthermore, new technologies of diffusion and amplification allow modification of sound source localisation and spatial dynamics, exploiting the human capacity to perceive the position of a sound source through differences in arrival time and intensity between the two ears – a perceptual mechanism that contemporary technologies such as binaural audio and other spatial audio systems have modelled and extended [6] – contributing to connecting the sound installation with the space it inhabits or itself defines.

The main characteristic of sound installations is that they define a space in its broadest sense: whether real or virtual, delimited in three dimensions by physical partitions or simply suggested by visual and auditory stimuli, whether in an interior or exterior architectural context, space emerges as an indispensable partner of sound [1], bringing not only timbral and perceptual enrichment but also modifying time through the user's experiential fruition.

Pioneering figures within this artistic domain include Iannis Xenakis, whose collaboration with Le Corbusier yielded the celebrated *Philips Pavilion* of 1958 [4, 31], alongside Bernhard Leitner, whose *Sound Spaces* [18] revealed the extraordinary possibilities inherent in acoustic spatialisation. Occupying dual positions as both architectural practitioners and musical composers, these innovators understood that crafting comprehensive sonic-spatial experiences demands designers to conceive sound as a fundamental structural component rather than supplementary ornamentation, whilst composers must regard acoustic space and sonic spatialisation as constitutive elements of musical composition itself. Although *Sound Art* remains sometimes overlooked by both musicological scholarship and by visual and textual artistic theories due to the inadequacy of most frameworks of either discipline to fully account for its complexity [8], its emergence signals a broader paradigmatic shift in the rise of *place* in sonic imagery, in which the audience assumes an expanded role as active participant and co-creator of the sonic-spatial experience [23].

The translation of these artistic paradigms into design practice finds theoretical foundation in *Sonic Interaction Design* (SID), an interdisciplinary field "positioned at the intersection of auditory display, ubiquitous computing, interaction design and interactive arts" [26]. Far from treating sound as a merely functional concern limited to noise reduction or alarm signalling, SID draws on interaction design, electronic music, cognitive science, and acoustics, and emerges as an active medium capable of enabling novel phenomenological and social experiences *through* and *with* interactive technologies [14]. Its applications might span wide ranges of design contexts: from the sonification of dining practices [9], to the development of affective interfaces through tactile-sonic interaction [3], to technology-assisted motor rehabilitation equipments [2]. These experiences share a common potential to inform innovative objects and spatial layouts that, through analogous technological mediation, are able to produce measurable positive effects on their users.

Building upon these foundations, more recent methodologies centred on *Sound-Driven Design* (SDD) are presently under investigation in emerging international research groups, going beyond SID approaches by pursuing human-centred, participatory frameworks for multisensory interaction grounded in auditory engagement [10]. Transitioning from *Sound Art* experiences and SID principles towards sound based spatial design paradigms requires integrating both fields, wherein technological sonic mediation – encompassing both high-tech and more accessible solutions – functions as a foundational instrument for sculpting spatial experience and cultivating meaningful interpersonal connection.

Expanding upon such methodologies, the expected outcome of this doctoral research comprises analytical evaluation frameworks and design tools applicable within architectural and interior design professional practice, positioning the sonic dimension as primary design consideration from project inception rather than subsequent addition. A methodologically relevant precedent is offered by Fraisse et al. [13], where sound installations in urban public spaces were implemented and their impact was evaluated through questionnaire-based observation of user behaviours, subjective emotional responses and fruition patterns, demonstrating the viability of structured user observation for evaluating sonic interventions in public spatial design contexts.

This research aspires to catalyse a paradigmatic transformation in spatial design practice, challenging the prevailing visual bias of contemporary design through sound-centered alternatives that seek not only evaluation strategies, but also the critical formulation of minimally invasive, small-scale interventions operating at the level of furnishings and objects (both physical and virtual) with the potential to positively influence the livability of public interiors in all their dimensions of social sustainability and accessibility [21], and which may progressively evolve into replicable design guidelines or best practices for designers, wherein multisensory and multidisciplinary dimensions inform design processes a priori rather than a posteriori.

Furthermore, focusing on the creation of sound-based design frameworks opens pathways for both the application of low-tech tools and the comprehensive use of new digital and virtual technologies, according to the different requirements of a space or enterprise. This technological spectrum ensures that sound-based spatial design remains accessible and adaptable across varied contexts and budgetary constraints, whilst maintaining the fundamental principle of sound as a primary spatial material. Low-tech solutions might include carefully designed acoustic furniture, strategically positioned sound-absorbing materials, or architecturally integrated resonant structures that shape sound passively. Conversely, high-tech interventions could employ spatialised audio systems, interactive sonic installations responding to user presence and behaviour, or digitally mediated soundscapes that adapt to temporal and social dynamics within the space.

Investigating this subject demands adaptive, interdisciplinary, boundary-crossing research methodologies, that will be organised across three principal phases.

Initially, extensive literature examination will establish the research within appropriate domains encompassing sound studies and spatial design, constructing theoretical foundations that bridge acoustic science, artistic practice, and interaction design.

Subsequently, the second phase develops hypothetical sound-based analytical frameworks applicable to spatial design practice, synthesising experiential qualities characteristic of *Sound Art* installations with user-centred principles fundamental to *Sonic Interaction* and *Sound-Driven Design*.

The final phase advances towards practical implementation, wherein these hypotheses undergo testing through didactical initiatives including design workshops, alongside design interventions in specific public interior environments awaiting regeneration, with the selection of these possible spaces being informed by acoustic measurement protocols.

By positioning sound as a primary spatial design material, whilst drawing upon technological, artistic, and information design methodologies, this research pursues theoretical and practical advances in generating more inclusive and responsive public interior environments.

The proposed sound-based framework, enabled through diverse technological approaches spanning low-technology passive strategies to high-technology interactive systems, seeks to furnish researchers, educators, and practitioners with concrete instruments for addressing contemporary social sustainability challenges, simultaneously revealing new perspectives on how immaterial interventions – rooted in artistic experimentation and technological mediation – can fundamentally reconstitute the quality of human interaction within communal spaces.

The trajectory from *Sound Art* to sound-based spatial design signifies not merely an aesthetic evolution, but a fundamental reconceptualisation of designing for users' experience, situating auditory interaction at the centre of socially sustainable spatial practices.

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