Experience of Personal Space Through Sound

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1 Abstract

This study explores how auditory stimuli influence personal space perception, expanding on theories of proxemics and environmental psychology. While personal space is traditionally understood as a physical boundary, this research investigates whether sound alone can create a sense of spatial encroachment.

Using the Personal (Sound) Space installation, this study shows how loudness, directionality, and predictability of sound affect perceived spatial boundaries. Participants engaged with a real-time auditory manipulation system, where environmental sounds were amplified and spatially repositioned. The actualization of the installation, indicate that auditory intrusion can elicit spatial discomfort and heightened awareness of personal boundaries, even in the absence of physical proximity. The installation represents the possibility to encroach into a participant's physical personal boundary without entering the field and only via sound propagation.

Findings suggest that sound-based spatial interventions could inform urban design, public space planning, and noise management strategies. While the study does not provide quantitative measurements, it highlights the need for further research, including EEG-based investigations, to systematically assess the cognitive and physiological effects of auditory encroachment.

By integrating psychological, artistic, and technological perspectives, this study challenges conventional proxemic theories and emphasizes the underexplored role of auditory perception in shaping personal space.

2 Introduction

Personal space is a fundamental concept in environmental psychology, referring to the invisible boundaries individuals maintain for comfort and security. Hall (1966)'s theory of proxemics categorizes interpersonal zones and highlights cultural and psychological factors that shape spatial perception. However, existing models primarily emphasize visual and physical encroachment, neglecting the potential influence of auditory stimuli.

In light of this gap, the present research hypothesizes that auditory stimuli alone can intrude upon personal space. A counter-hypothesis contends that physical proximity remains the primary determinant. Building on these perspectives, this study investigates whether sound properties, such as loudness, predictability, and directionality, impact personal space perception, particularly in urban environments where sound is an unavoidable factor. The counter hypothesis to this would be proximity of sound being irrelevant to the measurement of one's personal space.

To examine this phenomenon, an artistic installation, *Personal (Sound) Space*, was designed to simulate auditory encroachment. The installation amplifies environmental sounds and projects them into participants' perceived personal space, creating an immersive experience of auditory intrusion. Following each participant's engagement, a reflective discussion was conducted to gather qualitative insights, which are analyzed in this paper. These reflections, alongside the theoretical framework, suggest that auditory stimuli can provoke responses akin to physical space violations, manifesting as annoyance, increased stress levels, or even physiological reactions such as elevated cortisol levels in public settings.

Additionally, this study highlights a gap in existing research regarding the role of sound in spatial perception and its implications for public space design. It raises questions about noise pollution, the effectiveness of noise-canceling technologies, and how auditory intrusion shapes human behavior in shared environments.

Rather than aiming for empirical validation, this study seeks to illustrate the plausibility of auditory encroachment through artistic experimentation. By integrating psychological theory with interactive design, it challenges conventional understandings of proxemics and proposes a broader, multi sensory perspective on personal space.

3 Literature Review

3.1 Theoretical Background

Personal space, as defined in environmental psychology, refers to the physical and psychological boundaries individuals establish to maintain comfort and security in social contexts. Hall (1966) proxemics theory categorizes interpersonal distance into four primary zones—intimate, personal, social,

Figure 1: The installation layout of the project Personal (Sound) Space, exhibited as part of the Perspective in Design module (Hyperspace), within the Design and Computation M.A. at Technische Universität Berlin and Universität der Künste Berlin, hosted at the *New Practice* studio.

and public—each influencing human interaction and spatial behavior. Expanding on Hall's framework, Gifford (1983) introduced the distinction between perceived interpersonal distance (PIPD) and objective interpersonal distance (OIPD), emphasizing that spatial perception is shaped not only by physical measurements but also by cognitive and cultural interpretations.

While traditional research has primarily focused on visual and physical encroachments of personal space, the role of sound as a non-physical factor remains underexplored. The concept of *auditory intrusion*, which refers to the involuntary occupation of cognitive space through sound, presents a critical yet often overlooked dimension of spatial boundaries. Research in environmental psychology suggests that auditory stimuli's predictability, loudness, and pleasantness significantly influence perceived comfort in shared spaces (Blesser & Salter, 2007). Furthermore, studies on noise annoyance and cognitive stress (Glass & Singer, 1972) indicate that unwanted sound can trigger physiological and psychological stress responses comparable to those caused by physical proximity violations.

Additionally, sound's ability to travel through space creates another layer of intrusion, which can be considered from an architectural perspective. Architectural acoustics addresses how built environments influence sound propagation and, consequently, the perception of personal space.

3.2 Sound Perception and Spatial Cognition

John Cage's experimental work on auditory perception underscores sound's role in shaping spatial experience. His assertion that "silence does not exist, only the perception of it" highlights the omnipresence of sound in human awareness. Similarly, Alvin Lucier's *I Am Sitting in a Room* (1969) demonstrates how sound reshapes perceived space by altering its acoustic characteristics.

In architectural acoustics, Blesser and Salter (2007) introduced the concept of *aural architecture*, arguing that sound affects not only spatial navigation but also the subjective experience of enclosure. Neurological research (Zion Golumbic, Cogan, Schroeder, & Poeppel, 2013) suggests that spatial attention mechanisms are not solely visual but also auditory, reinforcing the idea that sound actively shapes spatial cognition.

3.3 Noise Annoyance and Personal Space Perception

Research on noise sensitivity (Weinstein, 1978) demonstrates that individuals exhibit varying tolerance levels for intrusive sounds, with highly noise-sensitive individuals experiencing stronger physiological stress responses. The World Health Organization (World Health Organization, 2011) guidelines on environmental noise highlight that prolonged exposure to unpredictable auditory stimuli correlates with cognitive fatigue and increased stress markers.

By integrating these perspectives, the present study frames auditory intrusion as an active agent in the negotiation of personal space. This research extends existing studies by investigating whether non-physical auditory stimuli can mimic physical spatial encroachment, thereby redefining proxemic theories to incorporate auditory dimensions.

4 Methodology

4.1 Conceptual Framework and Implementation

This study builds upon existing research in personal space, proxemics, and environmental psychology, particularly concerning auditory perception and its influence on spatial boundaries. The research integrates theories of interpersonal distance and sound perception, investigating how non-physical auditory stimuli can alter an individual's perception of personal space. Additionally, audio and signal processing techniques were employed to manipulate spatial perception through sound.

The project evolved organically through iterative experiments and observations, exploring sound as a tool for spatial manipulation. The work of contemporary artists such as John Cage and Alvin Lucier played a significant role in shaping the study's conceptual foundation. Notably, Lucier's *I Am Sitting in a Room* and *Music for Solo Performer* informed the experimental approach, while Cage's philosophical assertion that sound defines space through auditory perception was central to the study's premise.

The methodology involved analyzing how various sound properties, including volume, directionality, and predictability, affect perceived space and comfort levels. These findings informed the installation design, which aimed to create an interactive environment where participants could experience and reflect on auditory encroachment. Additionally, field experiments were conducted to measure the ambient soundscape of the exhibition, capturing elements such as chatter, footsteps, and sounds from adjacent installations to better understand sound propagation in space.

4.2 Installation as the Experiment

The experiment was conducted in a 300 m^2 exhibition space during a public studio event (February 18–21, 2024). The *Personal (Sound) Space* installation consisted of a central rotating chair surrounded by four Genelec 4-inch nearfield loudspeakers, arranged in a square, positioned approximately 45–120 cm from the participant. Environmental sounds (e.g., chatter, footsteps) were captured and transmitted live in real time via wireless Rode microphones (Wireless GO II), placed at distant points in the space. The audio routing and processing were managed using TouchDesigner, which assigned each microphone to a designated loudspeaker channel.

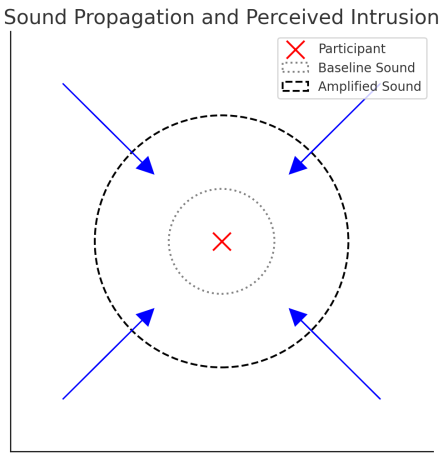

Figure 2: Schematic of the Personal (Sound) Space installation.

Sound Modulation Protocol:

- *Phase 1 (Baseline Calibration):* Speaker outputs matched the ambient noise level (60 dB-A).
- *Phase 2 (Experimental Manipulation):* Output levels increased by approximately 6–8 dB, creating an auditory illusion of closer proximity and mimicking spatial encroachment without physical presence.
- *Phase 3 (More Experimental Manipulations):* In some cases, microphone output were selectively increased to further enhance the perceived intrusion.

All dB measurements refer to dBFS (decibels relative to full scale), as the audio was processed and transmitted digitally. The use of digital processing was dictated by limitations in available equipment, making a fully analog setup unfeasible for this experiment.

The reasoning behind the 6–8 dB increase was to ensure a perceptually significant change in spatial presence. In psychoacoustics, relatively small decibel differences can still produce noticeable shifts in perceived loudness, owing to the logarithmic nature of human auditory perception. According to the Weber–Fechner law:

$$S = k \ln\left(\frac{I}{I_0}\right) \tag{1}$$

where S represents the perceived intensity (or loudness), I is the physical intensity of the stimulus, I_0 is a reference intensity, and k is a constant. Since perceived loudness increases logarithmically, a moderate decibel boost (6–8 dB) can create a pronounced shift in how "close" or "intrusive" a sound feels.

Volume (or loudness) is often perceived as a direct cue to how close or distant a sound source might be. Louder sounds tend to be interpreted as physically nearer, whereas reducing the sound level pushes it further away in the perceptual mix (Moore, 2012; Zahorik, 2002). By manipulating volume in real time, the installation effectively simulates shifts in proximity that can feel more immediate and immersive than mere physical repositioning of speakers would achieve.

5 Results and Discussion

5.1 Installation-Based Findings

The *Personal (Sound) Space* installation served as a real-world experimental implementation, allowing participants to experience auditory encroachment in a controlled setting. Preliminary observations revealed varying levels of sensitivity to auditory intrusion. Some participants reported an increased awareness of sound as a spatial boundary, particularly when sounds were unpredictably amplified. Others expressed discomfort due to the inability to visually locate the sound source, reinforcing the hypothesis that sound alone can influence personal space perception.

Figure 3: Photograph of the setup of Personal Sound Space installation with an empty rotating chair in the middle.

These findings suggest that auditory intrusion affects personal space perception independently of physical proximity. Participants' reactions highlight the potential applications of sound-based spatial interventions in urban and architectural design, particularly in settings such as public transit environments, where managing personal space is crucial.

Despite these insights, the study has limitations, most notably the absence of a formalized measurement tool for assessing auditory intrusion's impact on personal space. Future research should develop systematic methodologies to quantify these effects more precisely. One promising approach could involve using EEG (electroencephalography) to monitor brain activity patterns during exposure to auditory encroachments, providing deeper insights into neural responses associated with perceived spatial intrusion.

Figure 4: Participant experiencing the installation.

By demonstrating that non-physical sound can function as a spatial encroachment mechanism, this research lays the groundwork for innovative design considerations in shared environments. Future studies should incorporate techniques such as EEG analysis and behavioral assessments to refine our understanding of sound's role in spatial perception. Figures below demonstrate that the installation's design allows implementing a EEG headband in the experiment within it's borders.

Figure 5: Participant using a headband EEG for further suggestions of the research.

6 References

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