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Investigating Spatial and Affective Experience in Enclosed Spaces with Variations in Room Size and Surface Absorption

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Graduation Project

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Abstract

This research investigates how the physical properties of a room, specifically its size and surface absorption, influence our auditory spatial perception and affective responses. Although much research has been done on how physical properties of a room influence our spatial experience in the visual domain, their auditory counterpart remain relatively underexplored. We hypothesize that a room perceived to be less spacious can reduce our sense of comfort and safety, and increase our anxiety levels even in the absence of visual cues. To investigate this hypothesis, we designed nine virtual rooms across three room sizes (small, medium, large) and three surface absorption levels (low, moderate, high), which were acoustically illuminated with the same sound source. An experiment (n = 24) was then conducted where participants were blindfolded and asked to estimate each virtual room's dimensions, its perceived spaciousness, and rate their affective experience using Likert scale. Statistical analysis was performed on the collected data, and the results showed that varying these properties significantly influenced perceived spaciousness, and in certain conditions, virtual rooms evaluated as less spacious were associated with reduced comfort, safety, and higher anxiety. In addition to addressing the hypothesis, the result also reveals several observations on how participants' spatial perception of the virtual rooms is influenced by changes in room size and surface absorption.

I. Introduction

We can hear space, just as light allows us to see it. Sound reveals space by interacting with its physical components, enabling us to sonically experience its fundamental properties—size, shape, and boundaries. As sound waves travel, they reflect, diffuse, and are absorbed by surrounding surfaces. These interactions provide cues about a space's dimensions and boundaries, allowing us to construct a mental representation of our surroundings, even in the absence of vision.

A key aspect of spatial experience examined in this study is the perceived scale of a space and its influence on our affective states. A space that feels too small may induce a sense of claustrophobia and confinement (Pop et al., 2018), while an overly large space, such as a vast cathedral or an empty basement, can evoke detachment or disorientation (Blesser, 2009). The way a space sounds and the way it feels are deeply intertwined, giving rise to affective qualities we experience through listening. Despite the recognized role of spatial scale in shaping experience, much of the existing research has focused on visual perception, leaving its auditory counterpart relatively underexplored.

To address this gap, the present study investigates how auditory spatial cues related to room size and its surface absorption influence participants' spatial perceptions and affective responses. By isolating auditory inputs and removing visual context, the study explores whether the subjective sense of spaciousness corresponds to the objective size of a space and how these auditory variations influence affective states such as comfort, safety, and anxiety. The study systematically varies these conditions to examine their effects on participants' spatial experience.

The paper first introduces the theoretical background and related research, followed by the experimental methodology detailing the room simulation setup, participant procedures, and measurement techniques. The results section then presents findings on spatial perception, affective responses, and their statistical relationships, followed by a discussion that interprets the results and explores possible connections between spatial and affective responses.

2. Background

2.1 A Model of Auditory Experience

To understand how sound influences our affective state, we need a clear structure to describe how we interact with auditory stimuli. One practical approach is to divide this interaction into three stages: converting physical sound waves into neural signals, converting these neural signals into an internal representation of the external world, and interpreting this perception. Authors from different fields have used similar models to organize their research and explain their findings. For example, Blesser (2009, p. 14) provides a holistic framework from his interdisciplinary perspective of how we experience space, and he emphasizes the importance of distinguishing these stages clearly, labeling them *sensation*, *perception*, and *interpretation* to explain his reflection on auditory spatial experience. Similarly, Kaplanis et al. (2014) attempted to merge multiple empirical findings on reverberation cues and propose the "filter model" to guide his findings, which separates auditory experience into physical, perceptual, and affective domains. In their model, physical acoustic stimuli pass through sensory and cognitive filters, creating perceptual attributes (such as perceived room size) that subsequently lead to affective states (experiences such as feelings of comfort or anxiety).

An advantage of structuring auditory experience in this way is the ability to estimate affective responses from physical measurements, using perception as the connecting component. This approach involves two steps: first, identifying relationships between physical properties and perceptual attributes through psychophysics and perceptual models; second, linking these perceptual attributes to responses based on how the environment is interpreted. In this paper, our primary interest lies in the perception and affective response to physical room attributes, specifically its size and surface absorption.

In this study, we define affective states as any experience that can be valenced. That is, any experience that involves perceived goodness or badness, pleasantness or dislike (Zajonc, 1980). While perception tends to be relatively consistent across individuals, affective experience can vary widely depending on personal interpretations, experiences, and individual concerns (Blesser, 2009; Kaplanis et al., 2014). Such variability is consistent with broader affect-related literature, which indicates that affective responses often depend on whether an individual's concerns are satisfied or threatened (Desmet, 2008). Some concerns are context-specific; for example, the acoustics of a cathedral may evoke awe in spiritual ceremonies yet become unpleasant in classroom settings. However, other concerns are more common, such as the fundamental need to have adequate space to comfortably move and exist. This leads us to consider how the auditory perception of surrounding space may shape affective experience, a question we examine in more detail in the later subsection.

2.2 Auditory Perception of Apparent Room Size

We can estimate the size of an enclosed space through the properties of the reflected sound waves. The majority of studies propose reverberation time (the time it takes for sound to decay after the source stops), as a primary cue derived from reflected sound. However, its relationship to actual physical size is not straightforward. Research has shown that perceived room size can differ from a room’s physical, volumetric size, and that increases in reverberation time do not always translate to increases in apparent room size. In particular, changes in reverberation time in small rooms have been found to have no perceptual effect, suggesting that reverberation time alone is insufficient (see complete review by Kaplanis et al., 2014). Another contributing factor that has been proposed is early reflections, which are the first sound reflections that arrive shortly after the direct sound. These reflections carry information about the proximity and layout of nearby surfaces and have been shown to influence perceived room size independently of reverberation time (C. B. Pop & Cabrera, 2005). Still, recent findings suggest that the auditory system may apply different perceptual mechanisms depending on the volume and reverberant characteristics of the room

(Yadav et al., 2013). Therefore, the question of how we come to this sense of apparent room size, whether it comes from interaction between multiple cues, if a single cue dominates, or if it is context dependent, is actively discussed in current research.

Although how we do it is still debated, we have a general idea that we discriminate different room sizes through the temporal and spatial distribution of the reflected sound waves. For example, studies have shown that blindfolded individuals can assess a room's size based on speech and other reflected sounds (McGrath et al., 1996). Additionally, research by Sandvad (reviewed in Cabrera, 2007) demonstrates that people can accurately match room photographs with binaurally reproduced sounds that represent those spaces.

Room size and surface absorption both influence the properties of reflected sound waves. According to previous research, the physical dimensions of a space and the decay time of reverberation play a central role in how room size is perceived (Kaplanis et al., 2014). When room size is the only changing factor, while shape, surface material, and texture remain constant, smaller spaces tend to produce shorter reverberation times and denser patterns of early reflections. This is because sound waves travel shorter distances before striking a surface and are absorbed more quickly, providing cues that contribute to the perception of a smaller room. In contrast, when surface absorption is reduced (making surfaces more reflective) and the room dimensions remain constant, sound is absorbed more slowly and lingers longer in the space, resulting in extended decay times. These longer decay times can lead to the impression of a larger or more spacious environment, even when the actual size of the room remains unchanged. Although the mechanisms underlying auditory spatial perception are still debated, it is widely accepted that the relationship between acoustic cues and perceived room size is complex and nonlinear.

2.3 Properties of Space and Auditory Affective Response

This study explores how auditory spatial cues shape affective experience. It builds on the premise that a person's response to sound is influenced by the meaning assigned to auditory events. These meanings arise through the interaction between the sound source, the listener, and the surrounding context (Tajadura-Jiménez, 2008). Part of the response stems from the identification of the sound source, but another important part that we focus on is the spatial information about the space where the sound takes place and its relation to the perceiver. We don't only ask what the sound is, but where it is, how it moves, and what kind of space it occupies. For example: Is the sound approaching or receding? Is the surrounding space enclosed or open? These spatial cues become critical, informing how individuals anticipate possible actions one can take in that space. When an environment is perceived as highly confining, it may negatively influence our experience. Research on the emotional impact of spatial attributes can be understood through Appleton's prospect-refuge theory, which emphasizes that spatial arrangements enabling visibility (prospect) and concealment (refuge) are essential for evoking feelings of safety and comfort (Dosen & Ostwald, 2013). These complementary features shape one's sense of environmental control by allowing individuals to remain aware of their surroundings while also feeling protected. A disruption of this balance, such as excessive enclosure, may reduce perceived refuge and generate discomfort (Dawes & Ostwald, 2013). Ulrich (1983) similarly argues that spatial restriction can provoke immediate avoidance responses, such as anxiety or unease, even before conscious spatial interpretation occurs.

These theoretical perspectives suggest that our spatial experiences are tightly linked to core affective responses, prompting the question of how perceived spaciousness might shape them. We hypothesize that spaciousness, the subjective impression of available space, influences affective states by shaping one's sense of comfort, safety, or threat. Spaces that are perceived to lack available space may feel confining and claustrophobic. Conversely, spacious environments may be perceived more positively, as they can evoke a sense of freedom and ease of movement. Previous research has explored this interpretation: Both humans and animals maintain personal space and can experience discomfort or a sense of threat when confined in restrictive spaces (Graziano & Cooke, 2006). Other research has shown that personal space exists not only in our visual field but also in auditory ones (Làdavas et al., 2001). Insufficient space can contribute to stress and lead to avoidance behavior, and studies on environmental preferences consistently show that people are drawn to larger, more spacious environments rather than smaller, more constrained ones (Hur, Nasar, & Chun, 2010).

Furthermore, the impression of auditory spaciousness does not necessarily correlate with dimensional metrics such as width, length, or height. An extreme example of this effect occurs inside an anechoic chamber, where sounds from others feel distant and strange. It is as if we are placed in an infinitely open space with no physical walls confining us. This happens as the chamber's material completely absorbs sounds coming from the sound sources, leaving us without any spatial information about the boundaries of the chamber and rendering it "invisible" to our ears. With such conditions, an enclosed space can create the impression of an open field.

However, studies on affective responses to spatial perception have been primarily focused on visual stimuli, with auditory cues rarely explored. For instance, Boz and Demirkan (2020) examined how curved spatial boundaries and other environmental features such as size, light, texture, and color influence perceived spaciousness and affective response in virtual environments. They found that curved boundaries and larger, brighter spaces were consistently associated with greater perceived spaciousness and more positive affect. Similarly, Stamps investigated how variations in physical space properties influence perceptions of spaciousness, again relying only on visual cues (2009). While these studies investigate the relationship between spatial perception and affect, they do not address the role of sound in shaping these experiences. Their findings show changes in spatial properties, whether geometric or material can influence our perception of spaciousness and affective responses, and it might suggest that non-visual perception of space perhaps has a capacity to influence our experience in a similar manner.

At the same time, numerous practitioners have long used auditory space as a medium to evoke affective responses. Sound artists and musicians respond to the acoustical imprints of space, shaping their work to achieve their desired aesthetic and affective qualities. Architects manipulate acoustic environments to design spaces that enhance comfort, reduce stress, or foster engagement.

While architectural acoustics often focuses on optimizing intelligibility and reducing noise, the potential of sound to influence spatial perception and our affective experience remains an underexplored area of research.

One study that considers auditory cues in emotional appraisal is Tajadura-Jiménez et al. (2010), which investigated how room size and sound source position influence emotional responses in virtual environments. In this study, participants listened to a variety of emotionally categorized sound sources (e.g., aggressive growls, pleasant bird calls), while both the acoustic properties of the space and the source positions were systematically varied. Their results show that room acoustics size influences emotional appraisal of the sound source, and that the emotional valence of the sound itself plays an important role. For example, a threatening sound was experienced as more intense and negative when presented in a small, enclosed space compared to an open environment. However, their focus remains on how space modulates the emotional response to the sound source, rather than on how the space itself is perceived and evaluated. In contrast, our study isolates the role of the auditory space itself by presenting the same sound source across all conditions, allowing us to examine how variations in room acoustics influence perception. In addition, we introduce surface absorption as a second variable that we believe influences spatial experience.

2.4 Research Statement

Given these findings in the literature, we understand human auditory perception is highly attuned to spatial cues embedded in sound. These cues, conveyed through acoustic reflections and reverberation, allow us to construct internal representations of their surrounding environment, even in the absence of visual input. Among the physical characteristics that shape this experience, room size and surface absorption play a particularly important function, as they determine how sound propagates, reflects, and decays within an enclosed space. These acoustic parameters influence the perception of spaciousness, the subjective impression of available space, which has been shown to affect affective states such as comfort, safety, and anxiety, with environments that are perceived as less spacious capable in eliciting negative affective experience. These considerations suggest a worthwhile investigation into the relationship between the acoustic features of a room, the spatial perceptions they induce, and the affective responses they evoke. To guide this exploration, the study poses the following central question: *How do room size and surface absorption influence spatial perception and affective responses in enclosed spaces?*

Under this general question, we hypothesize that a room perceived to be less spacious can reduce our sense of comfort and safety, and increase our anxiety levels. First, we investigate how varying room size along with its surface absorption level influences the participants' spatial perception of room dimensions (width and length), subjective assessment of available space in a room (spaciousness), and sound source distance of the sound source used to acoustically illuminate the room. We are also interested in whether these spatial perceptions influence our sense of comfort, safety, and anxiety, which we understand as subjective, valenced experiences based on how individuals interpret their perception of the presented room.

3. Experiment

3.1 Sound Sources and Room Designs

To examine these questions, we created a set of virtual spaces that differed only in surface absorption and room size. This is because other physical properties of a space, such as its shape, content, or texture of the surface, influence our impression. Simulating such spaces with computational modelling is therefore advantageous as it allows us to focus specifically on the effects of room size and surface absorption. Furthermore, we selected footsteps as a sound source, it is a universally recognised sound source, and we lessened the likelihood of responses driven by the novelty of the stimulus. As with most available recordings, typical footstep sounds carry spatial information from the environment in which they were captured. To avoid this, we used footsteps recorded under anechoic conditions. Specifically, we selected a series of recordings from the AID dataset developed by Götz et al. (2022), captured in the anechoic chamber of the Fraunhofer Institute for Digital Media Technology IDMT in Ilmenau, Germany. In addition to that, a secondary speech source, generated using IBM Watson Text to Speech, was rendered spatially to deliver questionnaire prompts during the experiment. The questionnaire speech was also rendered with the spatial properties of each room, not to introduce new spatial cues, but to help in reminding the participants of the existing spatial impression created by the footstep stimulus at the time of evaluation.

Nine virtual spaces are presented in the experiment, each room with a unique combination of room size and surface material. There are three types of materials, which we label *Low*, *Moderate*, and *High* absorption, with three types of room sizes: *Small*, *Medium,* and *Large*. The specifics are detailed in **Table 1**, **Table 2,** and **Table 3.**

Table 1: Absorption Coefficient

Type	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Low	0.09	0.17	0.18	0.26	0.27	0.35	0.36
Moderate	0.16	0.31	0.32	0.45	0.46	0.59	0.6
High	0.53	0.85	0.87	0.88	0.90	0.91	0.92

Table 2: Room Dimensions

Type	Width (m)	Length (m)	Height (m)
Small	2.2	4.2	3
Medium	7	9	4
Large	13	16	6

Table 3: Reverb Time

Room Size	Low Absorption (s)	Moderate Absorption (s)	High Absorption (s)

Small	0.8	0.4	0.1
Medium	1.6	0.9	0.2
Large	2.6	1.4	0.3

3.2 Virtual Room Simulation

The virtual rooms used in this study were simulated using Pyroomacoustics (Scheibler et al., 2017), a Python package designed for room acoustic simulations. Pyroomacoustics employs the image source method, a technique that models sound reflections by generating virtual sources that represent reflections of the surfaces in an enclosed space. It is designed to facilitate the development and evaluation of audio processing algorithms and provide a structured framework for simulating acoustic environments. Another advantage of using the package is its ability to simulate the directionality pattern of microphones, which we then exploit to capture the ambiance of the designed rooms. To accurately present both the impression of the space and the direct sound of the footsteps, we implemented an IRT cross microphone array consisting of four simulated cardioid microphones arranged in a square formation with 18 cm spacing, each facing outward at 90° angles. This configuration provides four discrete recordings, which are then played back through a quadraphonic speaker setup.

Figure 1: Illustration of the simulated room

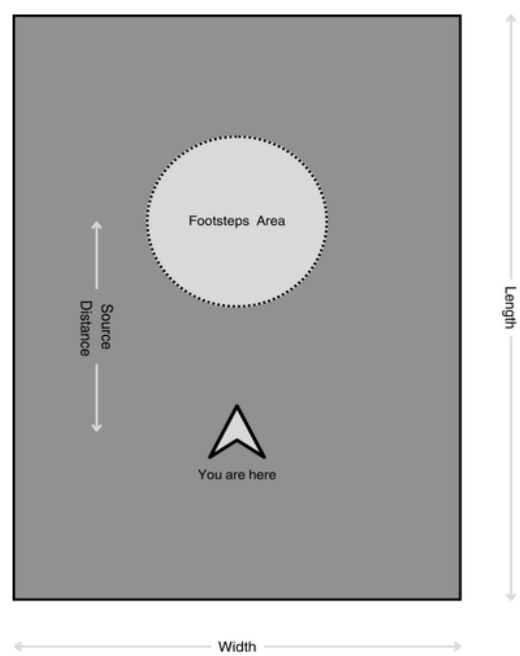

Illustration of a simulated room from the participant's auditory perspective. This illustration was provided during the experiment briefing to give participants an abstract representation of the rooms they were about to evaluate.

Both sound sources, the footsteps and the questionnaire speech, were placed at a distance of 2.1 meters from the center of the microphone array, with the footsteps positioned at ground level and the speech placed at a height of 1.6 meters. The midpoint between the microphone array and the virtual sound sources was always approximately at the center of the room, with a slight offset to introduce asymmetry between the left and right channels and to prevent excessive sweeping echoes in highly symmetrical room configurations.

3.3 Experimental Procedure

Before entering the experiment room, participants were blindfolded, and no participant had seen the dimensions of the room where the experiment took place. Participants were blindfolded to remove visual cues and ensure that spatial judgments were based exclusively on auditory information. This is crucial in isolating the auditory influence on participants' spatial experience. Without visual reference points, participants relied solely on acoustic cues to create a mental representation of the space.

The experiment follows a within-subjects design, where each participant experiences all combinations of room sizes and surface materials. The order of room size presentation was semi-randomized to compensate for the sequential comparison and adaptation effect on the participant. Each participant experienced three room sizes in one of six possible permutation orders, and all permutations were evenly distributed across the sample. Within each room size, the material conditions were always presented in a fixed order, from high to low absorption levels. During the briefing, participants are asked not to evaluate the sound of the footsteps but instead to focus on the acoustic response of the space. They are reminded further that the footsteps are only used to acoustically illuminate the room, and all of the questions are aimed at the experience of the room.

Three introductory rooms are presented to familiarize participants with the auditory spatial cues and calibrate their perceptions before the main phase of the experiment. The room sizes designed for the introductory exercises are not a subset of the room dimensions mentioned in the previous section. After each room presentation, participants are immediately asked questions verbally with the speech questionnaire. It is then grouped into two categories: Spatial Perception and Affective Response, and their verbal responses are then recorded for later analysis.

Figure 2: Experiment Setup

The experiment takes place in a sound-attenuated room with dimensions of 2.5 × 3 × 2.3 meters, designed to minimize external noise and acoustic reflections. Four KRK Rokit 6-inch speakers are positioned at a height of 1.2 meters, forming a 1.7 × 1.7-meter installation around the participant, who is seated at the center of the installation. Each speaker is placed ~70 cm from the participant, and the playback is driven by an RME Fireface UC audio interface, playing recordings at a 48 kHz sample rate and 16-bit resolution.

Figure 3: Experiment Session

Participants are seated in the middle of the installation while blindfolded with a sleeping mask. Each session takes approximately 20 minutes.

For the group Spatial Perception, each participant is asked to answer the following:

- What is the width of the room? (described to the participant as the distance between the wall to their left and right)
- What is the length of the room? (described to the participant as the distance between the wall to their front and back)
- How far are the footsteps from you?
- How spacious is this room to you? One being not at all spacious and nine being very spacious.

For the group Affective Response, the participant is asked to rate the following:

- How pleasant is your overall sonic experience? One being not pleasant at all and nine being very pleasant.
- How comfortable do you feel in this room? One being not comfortable at all and nine being very comfortable.
- How safe do you feel in this room? One being not safe at all and nine being very safe.
- How anxious do you feel in this room? One being not anxious at all and nine being very anxious.

Pleasantness was included both to gauge the overall valence of the experience and to help balance the questionnaire, which contained two positively valenced items (comfort and pleasantness) and two negatively valenced ones (safety and anxiety). Additionally, the selection of these items was informed by previous studies on claustrophobic responses to enclosed spaces (e.g., Pop et al., 2018). The experiment briefing guide, which contains the questionnaire along with the explanations, is provided in the appendix section. Participants were asked to study the document and encouraged to raise any questions they might have before the experiment starts.

3.4 Analysis Method

A two-way repeated measures ANOVA (RM-ANOVA) was conducted to assess the effects of Room Size (Small, Medium, Large) and Surface Absorption (High, Moderate, Low) on perceptual responses. This method was chosen due to the within-subjects experimental design, wherein each participant provided responses under multiple conditions. RM-ANOVA allows for the assessment of the main effects of each factor while accounting for individual differences, as well as potential interaction effects, which would indicate whether the impact of one factor depends on the level of the other. If a significant main effect or interaction is found, further post-hoc analysis will be conducted to explore the nature of these differences.

For post-hoc analysis, paired t-tests were performed to compare different room sizes within each material condition. This approach was selected to maintain the within-subjects design while providing pairwise comparisons of conditions. Since multiple comparisons were conducted within the same sample, the Holm-Bonferroni correction was applied to account for the accumulation of p-values with each additional comparison, consequently reducing the likelihood of finding significant differences by chance. The statistical significance threshold was set at $p < 0.05$, while comparisons with $0.05 \leq p < 0.10$ were classified as trending toward significance.

4. Results

Participants were recruited through convenience sampling via personal contacts and through announcements distributed via student mailing lists at Leiden University. The experiment took place in the Experimental Linguistics Laboratory at Leiden University, with data collected between January 2025 and March 2025. Participants consisted predominantly of students, along with some members of the general public. Each participant completed trials across nine room conditions, formed by combining three room sizes with three levels of surface absorption. The final dataset consisted of 216 observations, collected from 24 participants aged 19 to 35 years (67% female, 33% male). In each condition, participants rated eight variables: four affective (pleasantness, comfort, safety, anxiety) and four spatial (spaciousness, estimated width, length, and sound source distance). All participants were recruited voluntarily and gave informed consent for both data use and recording. No hearing issues were reported.

4.1 RM-ANOVA

A repeated-measures ANOVA was conducted to examine the effects of room size and surface absorption on spatial perception and affective response variables. Room size had a significant effect on all affective variables (pleasantness, comfort, safety, and anxiety), with the strongest effect observed for anxiety ($\eta^2 = .077$). It also significantly affected all spatial perception variables (spaciousness, estimated width, estimated length, and estimated distance), with the largest effect found in spaciousness ($\eta^2 = .121$).

Surface Absorption had a particularly strong effect on spaciousness ($\eta^2 = .290$) and significantly influenced estimated width, length, and distance, but had no significant impact on affective responses. Furthermore, we found no interaction effects between Room Size and Surface Absorption for any of the measured variables. A summary of significant results is presented in Table 1, and the full ANOVA output is provided in Appendix Table A1. Based on these results, we conduct post hoc pairwise comparisons using paired t-tests to explore specific condition differences.

Table 1

Significant RM-ANOVA results for Room Size & Surface Absorption Variables

Variable	Source	F	p-value	η^2
Pleasant	Room Size	6.8431	0.0025	0.0330
Comfortable	Room Size	9.1547	0.0004	0.0492
Safety	Room Size	6.5495	0.0031	0.0318
Anxiety	Room Size	15.9088	< .0001	0.0765
Spaciousness	Room Size	18.5305	< .0001	0.1209
	Surface Absorption	32.0852	< .0001	0.2904
Estimated Width	Room Size	15.5860	< .0001	0.0834
	Surface Absorption	12.5956	< .0001	0.0956
Estimated Length	Room Size	13.1827	< .0001	0.0596
	Surface Absorption	8.6617	0.0006	0.0878
Estimated Distance	Room Size	15.2374	< .0001	0.0914
	Surface Absorption	7.4506	0.0016	0.0595

Please refer to Appendix Table A for the full RM-ANOVA report.

Effect sizes (η^2) indicate the variance explained by each factor. For Surface Absorption, the largest effect was on Spaciousness ($\eta^2 = 0.290$) and the smallest on Pleasantness ($\eta^2 = 0.0029$). For Room Size, the largest effect was also on Spaciousness ($\eta^2 = 0.121$) and the smallest on Pleasantness ($\eta^2 = 0.033$).

4.2 Post Hoc Analysis: Spatial Perception Across Room Sizes and Surface Absorption

This section presents the post hoc analysis using paired t-tests for spatial perception variables. The spatial perception group t-test was conducted from two perspectives: first, comparing responses across different room sizes within each surface absorption level, and second, comparing responses across different absorption levels within each room size. This approach was taken due to the significant effects observed in the RM-ANOVA for both surface absorption and room size in spatial perception.

Figure 1: Boxplot of Spatial Perception Responses

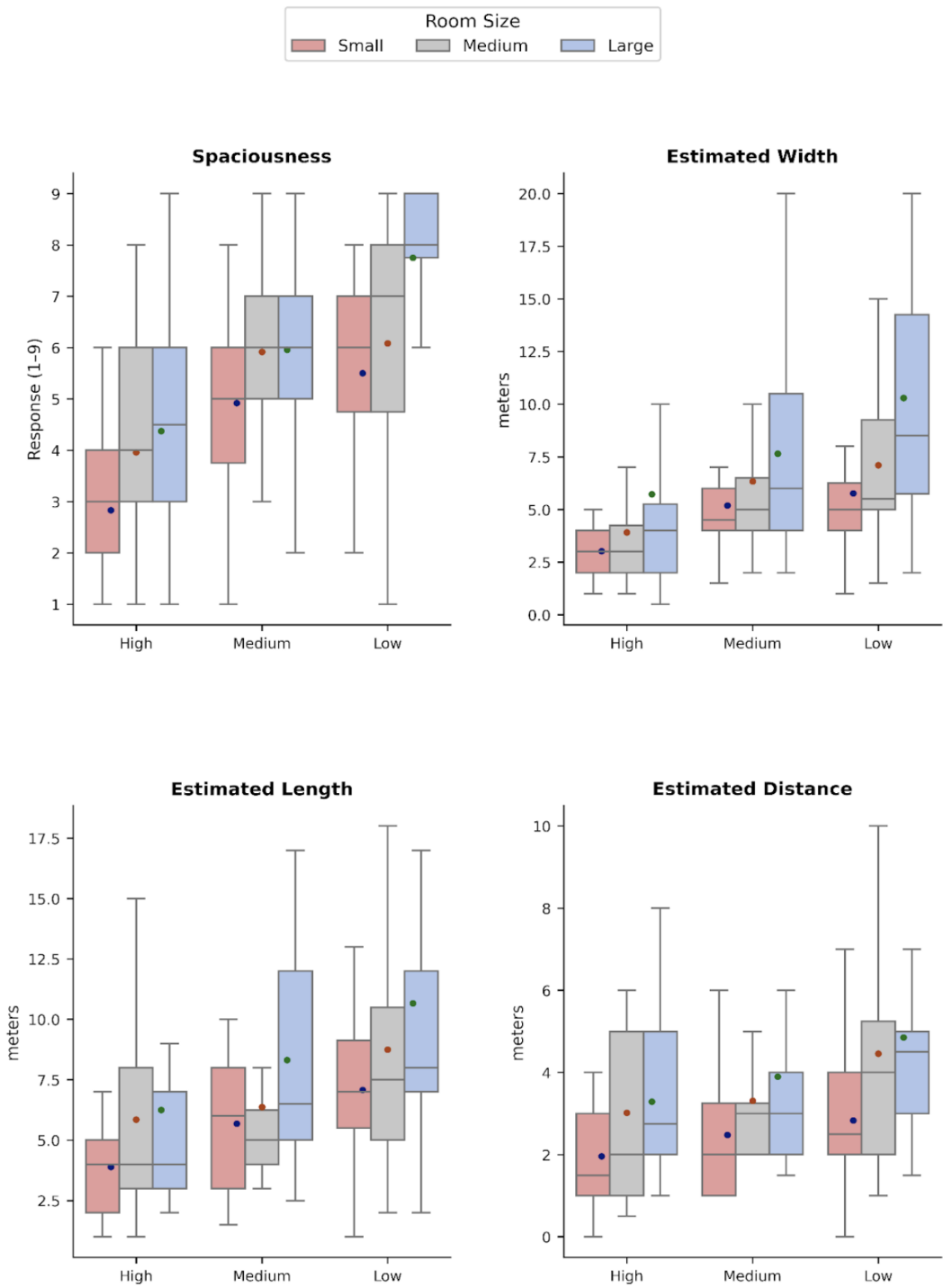

Figure 1 *illustrates the perceived spatial dimensions across different room sizes (Small, Medium, and Large) and Surface Absorption levels (High, Moderate, and Low). All variables are measured on a Likert scale ranging from 1 to 9.*

4.2.1 Spaciousness

Spaciousness ratings generally increased with room size and decreased surface absorption, and it is a response that was the most significantly consistent across combinations of room sizes and absorption types. The positive relationship between room size and spaciousness ratings suggests that participants were, to some extent, able to discriminate the amount of available space based solely on auditory cues. We have also observed that high absorption dramatically increased the variability of responses in large room conditions. Participants appeared to interpret this space as either spacious or confining, perhaps because large spaces are typically associated with longer reverberation, which was absent here due to the high absorption. In contrast, the large room with low absorption, which results in a longer reverberation time, was rated most consistently and generally received the highest spaciousness ratings. In contrast, a small room with high absorption received the lowest spaciousness ratings. Interestingly, the small room with low absorption received slightly higher spaciousness ratings (Small | Low: M = 5.50, SD = 1.91) than the medium room with high absorption (Medium | High: M = 3.96, SD = 1.94), despite having smaller physical dimensions.

4.2.2 Estimated Width and Length

Estimated width and length ratings generally increased with increasing room size and lower surface absorption. We recognized that although the rooms were modeled as shoebox-shaped (room is longer than it is wide), in many cases, width and length ratings were similar. Participants did not appear to consistently reflect this asymmetry in their dimension estimates. Length estimates also tended to show greater variability, and it perhaps reflected the increased difficulty of perceiving length from auditory cues. We have also observed that surface absorption appears to influence estimated dimensions within the same room size. As observed in the spaciousness rating, participants may have inferred that they are perceiving a larger space through longer reverberation. An unexpected trend can be observed in Table 2, where the standard deviation of the estimated width increases as the room size increases. Less deviation in smaller spaces might be caused by the proximity of the walls to the listener in the smaller room, allowing them to judge the area of the room more precisely.

4.2.3 Sound source distance

Perceived sound source distance generally increased with room size, but showed less consistent patterns across surface absorption levels. The effect of room size was statistically significant (η^2 = .091), with small rooms being perceived as having the closest sound source and large rooms the furthest (see Table 3). In contrast, differences across surface absorption levels were less consistent and often not significant (see Table 4). This perhaps indicates in this experiment, the perceived sound source distance was influenced more by the room's physical dimensions than by its surface properties.

Table 2

Descriptive Statistics of Spatial Perception Responses

Room Size	Surface Absorption	Spaciousness (1-9)		Est. Width (m)		Est. Length (m)		Est. Distance (m)	
		mean	std	mean	std	mean	std	mean	std
Small	High	2.83	1.46	3.02	1.45	3.90	2.13	1.96	1.26
	Medium	4.92	1.93	5.19	3.66	5.69	2.56	2.48	1.57
	Low	5.50	1.91	5.77	3.50	7.08	3.16	2.83	1.69
Medium	High	3.96	1.94	3.92	3.76	5.85	4.52	3.02	1.93
	Medium	5.92	1.32	6.33	4.23	6.38	4.13	3.31	1.89
	Low	6.08	2.21	7.10	3.89	8.75	4.55	4.46	3.08
Large	High	4.38	2.14	5.73	6.41	6.25	6.30	3.29	1.99
	Medium	5.96	1.78	7.65	4.73	8.31	4.44	3.90	2.26
	Low	7.75	1.42	10.29	6.81	10.67	7.91	4.85	3.09

Please note that not all variables show statistically significant results. For more details on the comparison between room types, please refer to Table 3 and Table 4.

Table 3

Spatial Perception comparison of different Room Sizes within Surface Absorption Level

Material	Variable	Comparison	Significance	Raw P-Value	Corrected P-Value
High	Spaciousness	Small - Medium	Significant	0.0086	0.0172
		Small - Large	Significant	0.0040	0.0119
	Estimated Width	Small - Large	Trending	0.0403	0.0807
		Medium - Large	Trending	0.0209	0.0627
	Estimated Length	Small - Medium	Significant	0.0133	0.0400
		Small - Large	Trending	0.0490	0.0980
	Estimated Distance	Small - Medium	Significant	0.0115	0.0230
		Small - Large	Significant	0.0022	0.0065
Medium	Spaciousness	Small - Medium	Significant	0.0223	0.0486
		Small - Large	Significant	0.0162	0.0486
	Estimated Width	Small - Large	Trending	0.0190	0.0571
	Estimated Length	Small - Large	Significant	0.0027	0.0082
		Medium - Large	Significant	0.0220	0.0439
	Estimated Distance	Small - Large	Significant	0.0013	0.0038
Low	Spaciousness	Small - Large	Significant	< .0001	< .0001
		Medium - Large	Significant	0.0021	0.0041
	Estimated Width	Small - Medium	Trending	0.0717	0.0717
		Small - Large	Significant	0.0009	0.0026
		Medium - Large	Trending	0.0338	0.0677
	Estimated Length	Small - Large	Trending	0.0293	0.0880
	Estimated Distance	Small - Medium	Significant	0.0043	0.0087
		Small - Large	Significant	0.0001	0.0004

The complete table can be found in Appendix Table C.

Table 4

Spatial Perception comparison of different Surface Absorption Levels within Room Sizes

Room Size	Variable	Comparison	Significance	Raw P-Value	Corrected P-Value
Small	Spaciousness	High - Medium	Significant	0.0001	0.0002
		High - Low	Significant	< .0001	0.0001
		Medium - Low	Trending	0.0796	0.0796
	Estimated Width	High - Medium	Significant	0.0059	0.0118
		High - Low	Significant	0.0017	0.0051
	Estimated Length	High - Medium	Significant	0.0107	0.0213
		High - Low	Significant	0.0002	0.0005
		Medium - Low	Significant	0.0209	0.0213
	Estimated Distance	High - Low	Trending	0.0204	0.0612
Medium	Spaciousness	High - Medium	Significant	0.0002	0.0006
		High - Low	Significant	0.0004	0.0009
	Estimated Width	High - Medium	Significant	0.0009	0.0026
		High - Low	Significant	0.0009	0.0026
	Estimated Length	High - Low	Trending	0.0295	0.0884
		Medium - Low	Trending	0.0460	0.0920
	Estimated Distance	High - Low	Trending	0.0213	0.0630
Large	Spaciousness	High - Medium	Significant	0.0104	0.0104
		High - Low	Significant	< .0001	< .0001
		Medium - Low	Significant	< .0001	< .0001
	Estimated Width	High - Low	Trending	0.0187	0.0561
	Estimated Distance	High - Low	Trending	0.0209	0.0627

The complete table can be found in Appendix Table B.

4.3 Post Hoc Analysis: Affective Responses Across Room Sizes

The post hoc analysis of affective response variables was conducted using paired t-tests, comparing different room sizes within each absorption condition. This one-way comparison was selected because changes in surface absorption did not result in statistically significant differences in affective responses. While surface absorption had a noticeable influence on spatial perception, its effect on comfort, safety, and anxiety is inconsistent. It is also observed that the affective response group shows greater variability in spatial perception responses.

Figure 2: Boxplot of Affective Responses

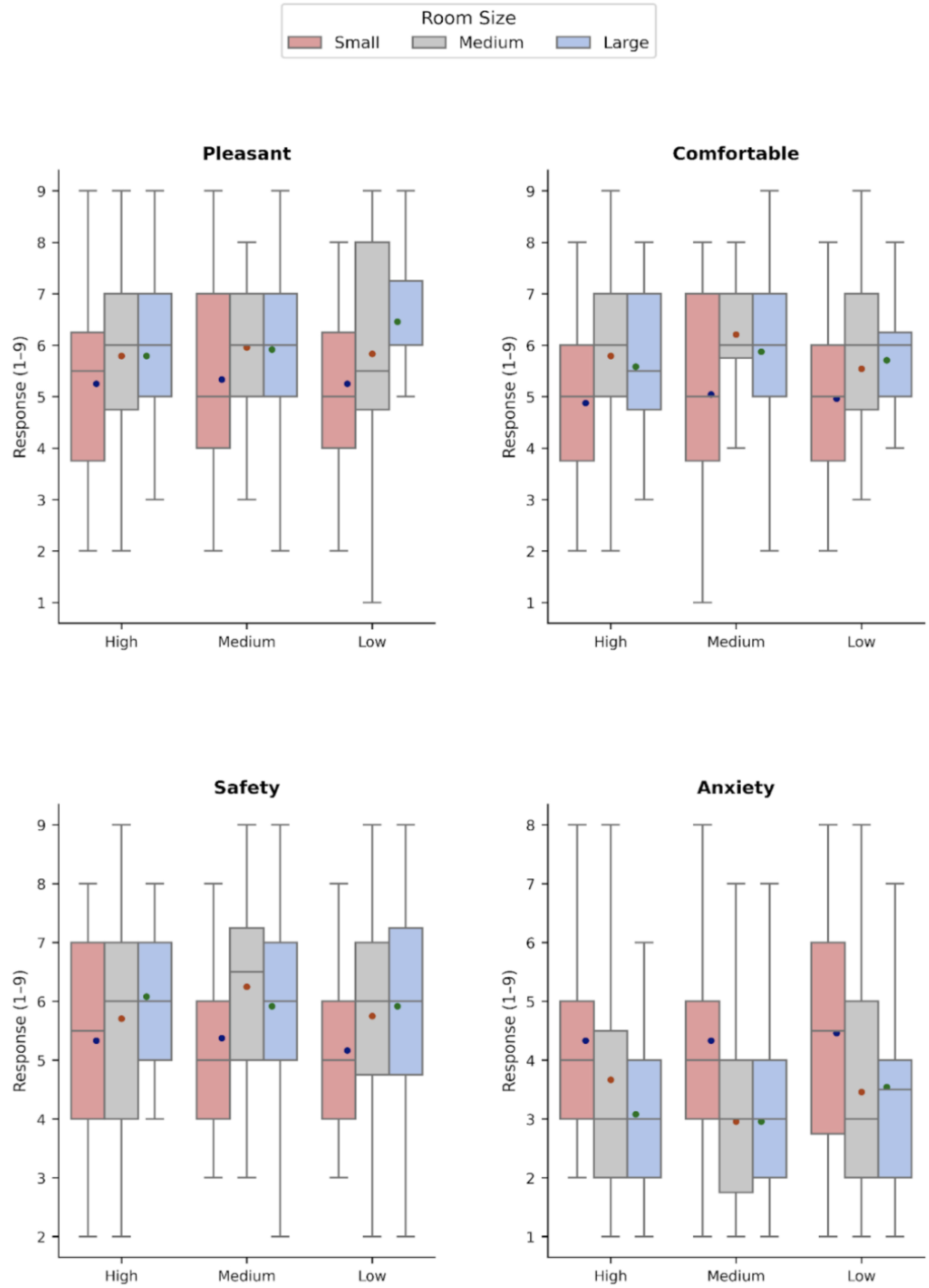

Figure 2 *illustrates the perceived spatial dimensions across different room sizes (Small, Medium, and Large) and Surface Absorption levels (High, Moderate, and Low). All variables are measured on a Likert scale ranging from 1 to 9.*

4.3.1 Pleasantness

Pleasantness ratings were generally inconsistent across room types and absorption conditions, and, unlike other affective measures in this experiment, pleasantness appears to be more influenced by individual preferences than by spatial changes in the experiment. Pleasantness can be observed to be somewhat lower in small rooms, although the differences are not always statistically significant. The only significant difference was observed between small and large rooms in the low absorption condition, where the large room was rated as most pleasant (Large | Low: M = 6.46, SD = 1.67) and the small room as least pleasant (Small | Low: M = 5.25, SD = 1.85). Interestingly, while other room conditions showed scattered pleasantness ratings, the large room with low absorption was consistently rated by participants as the most pleasant room type.

4.3.2 Comfort & Safety

Comfort and safety ratings tended to be lower in smaller rooms, and this observation aligns with our expectation that spaces that are perceived as confining might cause discomfort to the participant. This pattern was observed most clearly in the moderate and high absorption conditions, where smaller rooms were consistently rated as less comfortable and less safe. It can also be seen that the mean comfort and safety ratings in large rooms were slightly lower or comparable to those of medium rooms under both high and moderate absorption conditions. This suggests that increased room size does not always lead to higher comfort or a greater sense of safety, perhaps after a sufficient sense of spaciousness is already established.

We have also observed that the majority of participants agree that the medium room with moderate absorption received the highest ratings for both comfort (M = 6.21, SD = 1.50) and safety (M = 6.25, SD = 1.59) across all conditions. However, a contrasting difference between safety and comfort ratings can be seen in the large room with low absorption. Safety ratings show a wide spread, while comfort ratings are more consistent among participants. We have also observed that the second participant reflected that the reverberant footsteps became “horror-like”. This suggests that even though the space was perceived as spacious, the environment may have shaped the emotional impression of the sound source perceived by the participants.

4.3.3 Anxiety

Anxiety ratings tended to be higher in smaller rooms and lower in medium and large rooms. This pattern was observed across all absorption conditions, making anxiety the most consistent affective variable in terms of statistical significance and effect size. Notably, there were no significant differences between medium and large rooms, suggesting that anxiety may not improve once a certain spatial threshold is reached. The highest anxiety level was found in the small room with high absorption (Small | High: M = 4.33, SD = 1.83), while the lowest levels were observed in the medium and large rooms with moderate absorption (Medium | Moderate: M = 2.96, SD = 1.78; Large | Moderate: M = 2.96, SD = 1.49). The result supports the idea that anxiety level can be sensitive to an inadequate sense of spaciousness, which levels off when sufficient space is perceived.

Table 5

Descriptive Statistics of Affective Response

		Pleasant (1-9)		Comfortable (1-9)		Safety (1-9)		Anxiety (1-9)	
Size	Material	mean	std	mean	std	mean	std	mean	std
Small	High	5.25	1.94	4.88	1.96	5.33	1.90	4.33	1.83
	Moderate	5.33	1.86	5.04	1.90	5.38	1.47	4.33	1.55
	Low	5.25	1.85	4.96	1.65	5.17	1.61	4.46	2.06
Medium	High	5.79	1.98	5.79	2.02	5.71	2.05	3.67	2.18
	Moderate	5.96	1.40	6.21	1.50	6.25	1.59	2.96	1.78
	Low	5.83	2.06	5.54	1.77	5.75	1.78	3.46	2.00
Large	High	5.79	1.86	5.58	1.77	6.08	1.61	3.08	1.72
	Moderate	5.92	1.77	5.88	1.65	5.92	1.53	2.96	1.49
	Low	6.46	1.67	5.71	1.57	5.92	1.89	3.54	1.93

Please note that not all variables show statistically significant results. For more details on the comparison between room types, please refer to Table 6.

Table 6

Affective Response comparison between Room Sizes within Surface Absorption type

Material	Variable	Comparison	Significance	Raw P-Value	Corrected P-Value
High	Comfortable	Small - Medium	Significant	0.0155	0.0464
	Anxiety	Small - Medium	Significant	0.0148	0.0296
		Small - Large	Significant	0.0037	0.0110
Moderate	Comfortable	Small - Medium	Significant	0.0058	0.0175
	Safety	Small - Medium	Significant	0.0062	0.0187
		Small - Large	Trending	0.0292	0.0585
	Anxiety	Small - Medium	Significant	0.0026	0.0052
		Small - Large	Significant	0.0001	0.0002
Low	Comfortable	Small - Large	Trending	0.0256	0.0768
	Pleasant	Small - Large	Significant	0.0022	0.0066
	Safety	Small - Large	Trending	0.0281	0.0842
	Anxiety	Small - Medium	Significant	0.0250	0.0500
		Small - Large	Significant	0.0142	0.0425

The complete table can be found in Appendix Table C.

5. Discussion

From the results above, we observe differences in participants' reactivity to spatial perception and affective responses. Changes in spatial perception appear more linear (for example, an increase in room size positively influences the spaciousness rating), whereas changes in affective response are only observed in certain conditions (such as anxiety responses shifting when participants perceive a smaller space). While the change is modest, it may suggest that rooms lacking perceived available space, or that feel confining, are associated with these affective responses. This observation is also reflected in the fact that comparisons between medium and large rooms did not reveal significant differences in affective responses. It suggests that once an environment reaches a sufficient threshold of spaciousness, it might no longer trigger a negative affective response. In contrast, comparisons between small and medium rooms revealed clearer differences in both spaciousness and affect ratings, despite no significant differences in participants' estimated room dimensions. Environments evaluated as less spacious, even based solely on auditory cues, were more likely to elicit negative affective responses such as anxiety and reduced comfort level.

A further point of interest worth noting is how participants might respond negatively due to the perceived closeness of the footsteps. In the smaller room, as the data presents, footsteps are perceived significantly closer to the participant, and statements such as "that's too close" are observed during the experiment. We suspect that this effect might have influenced the negative response towards the room where the footsteps are perceived as invading their space. The opposite is also observed when the larger room has the furthest estimated distance of the footsteps' location.

The comparison of perceived dimensions and spaciousness between room sizes small and medium shows a notable observation: Although there is no significant difference in the perceived dimensions, spaciousness ratings are significant. This shows that, in this experiment, participants are perhaps intrinsically aware that there is a difference in the available space surrounding them, even when their approximation does not differ significantly. During the experiment, it was also observed how participants' personal experience influenced their spatial interpretation of the recording. Some participants referred to their past encounters with different spaces (statements such as "it reminds me of a long school corridor, the width would be 4 meters") to construct a mental representation of the virtual room. This is unexpected as we underestimate how much influence subjective interpretation has on the objective measurement of the room when visual cues are absent. Nevertheless, this study supports the idea that individuals can estimate different room sizes purely from auditory cues.

The finding that surface absorption levels do not have a consistent effect on affective responses is unexpected. While lower absorption increases perceived spaciousness, it does not directly translate to higher comfort, safety, or lower anxiety. This contrasts with the influence of increased spaciousness through room size, which seems to modestly improve the comfort, safety, and anxiety rating. Furthermore, we are also aware that perhaps reverberation influences the impression of the sound source itself. For example, footsteps with longer reverberation might result in higher anxiety than those in high-absorption environments. Although we have explicitly asked the participants to focus on the acoustic response rather than the footsteps, it is understandable that it can be difficult to distinguish one's responses between those aimed toward the spatial impression or the sound source.

We also observed that participants' responses to pleasantness and comfort can differ. For example, large rooms with low absorption sometimes resulted in positive ratings for pleasantness while eliciting lower ratings for comfort. Considering the circumplex model of affect, which maps emotional experience along valence and arousal axes (Russell, 1980), we observe that large, highly reverberant spaces in this experiment may lead not only to higher pleasantness ratings, but also to a heightened state of arousal that does not always correspond to comfort.

5.1 Limitations and Future Considerations

The main limitation of the study stems from the specific context in which the experiment is conducted. The procedure of the experiment, the space where the installation took place, the way the virtual room is presented, and even the fact that the participant is aware that this is an experiment influence the result. Therefore, we would like to acknowledge that the findings in this study are only valid in the context of this experiment. In the real environment, we are aware that the affective response to a space always depends on the context at that point in time. For example, we can imagine a small room being evaluated as comfortable when we are in the company of friends or family, or as a place of safety when the circumstance is evaluated as harmful. Although the nature of the experiment is designed to minimize the influence of such contexts, future research should be done in more specific scenarios to see how the results can differ or coincide.

Furthermore, the experiment was conducted with simulated propagation of sound captured with simulated microphones, which was then presented with a speaker set up in a lab environment. Although the resulting virtual rooms are acoustically convincing, we cannot claim that the results can be applied in a real room without further experiments. In addition, we are not able to determine the extent to which the physical lab room where the experiment takes place influences participants' affective response and spatial perception. Despite the fact that the lab room is designed to minimize sound reflections off its surfaces, some participants may still have been aware that they were seated in a small room with highly absorptive material (as demonstrated in the experiment, participants can discriminate the size of the room even with minimum reverberation). When participants verbally answered the questionnaires, the virtual room did not simulate the reflection of their voice, and the acoustics of their voice were determined by the real room where the experiment took place. This may have revealed the spatial properties of the lab room, even though participants were blindfolded.

Another important limitation that we would like to acknowledge is the fixed presentation order of the absorption level during the experiment. We suspect that it has an influence, especially on the spatial perception responses from the participants. For example, we did not expect that lowering surface absorption would significantly increase the estimated dimensions. Since the absorption level is always presented from high to low absorption, participants may have gradually increased their estimates as reverberation increased. A more reverberant room can be evaluated as larger because it follows a less reverberant one. Future studies that fully randomized the order of both surface absorption and room size should be conducted to confirm or disprove the result observed in this study.

6. Conclusion

We set out to investigate how the physical properties of an enclosed space influence an individual's experience in the space. By isolating auditory cues and eliminating visual information, we aimed to explore the relationship between perceived spatial scale and affective states such as comfort, safety, and anxiety. Our findings show that the room's surface absorption and dimensions influence participants' spatial perception and that perceived room size shapes our experience. Additionally, we observed that spatial perception is fairly consistent among participants. They were able to holistically assess the amount of space available, even when their dimensional estimations were inaccurate in some rooms. In addition to that, our experiment supports the idea that people can approximate the size of a space through auditory cues alone.

We also found that spaciousness in the auditory domain is perhaps more intricate than its visual counterpart. Participants' judgment is often very nuanced and seems to require an abstract representation of space constructed from personal experience. It is also apparent that spatial perception modulates how participants perceive and evaluate the sound source, with footsteps appearing closer in smaller rooms and more haunting in larger, more reverberant environments. Architectural studies emphasizing the preference for visually spacious environments might benefit from incorporating the influence of subtle and complementary auditory impressions.

Lastly, this experiment highlights the potential of auditory impressions as a medium, whether in their functional role in architecture or their subjective nature in artistic practice. As more research converges on this topic, we can expect not only new insights into how we perceive and interpret auditory space but also a deeper understanding of how we fundamentally interact with and experience space.

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Appendix

Table A
RM-ANOVA results for Room Size & Surface Absorption Variables

Variables	*Source*	*ddof1*	*ddof2*	*F*	*p-value*	η^2
Pleasant	Room Size	2	46	6.8431	0.0025	0.0330
	Surface Absorption	2	46	0.2473	0.7819	0.0029
	Room Size * Surface Absorption	4	92	0.7635	0.5517	0.0064
Comfortable	Room Size	2	46	9.1547	0.0004	0.0492
	Surface Absorption	2	46	0.4722	0.6266	0.0066
	Room Size * Surface Absorption	4	92	0.4354	0.7827	0.0039
Safety	Room Size	2	46	6.5495	0.0031	0.0318
	Surface Absorption	2	46	0.2135	0.8085	0.0033
	Room Size * Surface Absorption	4	92	0.8092	0.5224	0.0054
Anxiety	Room Size	2	46	15.9088	< .0001	0.0765
	Surface Absorption	2	46	0.6257	0.5394	0.0086
	Room Size * Surface Absorption	4	92	0.8842	0.4767	0.0070
Spaciousness	Room Size	2	46	18.5305	< .0001	0.1209
	Surface Absorption	2	46	32.0852	< .0001	0.2904
	Room Size * Surface Absorption	4	92	2.3878	0.0566	0.0267
Estimated Width	Room Size	2	46	15.5860	< .0001	0.0834
	Surface Absorption	2	46	12.5956	< .0001	0.0956
	Room Size * Surface Absorption	4	92	0.8015	0.5273	0.0084
Estimated Length	Room Size	2	46	13.1827	< .0001	0.0596
	Surface Absorption	2	46	8.6617	0.0006	0.0878
	Room Size * Surface Absorption	4	92	0.4424	0.7776	0.0056
Estimated Distance	Room Size	2	46	15.2374	< .0001	0.0914
	Surface Absorption	2	46	7.4506	0.0016	0.0595
	Room Size * Surface Absorption	4	92	0.6477	0.6299	0.0054

Table B

Spatial Perception and Affective Response Comparisons Across Different Room Sizes Within Surface Absorption

Room Size	*Variable*	*Comparison*	*t-Statistic*	*Raw P-Value*	*Corrected P-Value*	*Significance*
Small	Spaciousness	High-Medium	-4.7136	< .0001	0.0002	Significant
Small	Spaciousness	High-Low	-5.1616	< .0001	< .0001	Significant
Small	Spaciousness	Medium-Low	-1.8342	0.0796	0.0796	Trending
Small	Estimated Width	High-Medium	-3.0349	0.0059	0.0118	Significant
Small	Estimated Width	High-Low	-3.554	0.0017	0.0051	Significant
Small	Estimated Width	Medium-Low	-1.3198	0.1999	0.1999	Not Significant
Small	Estimated Length	High-Medium	-2.7789	0.0107	0.0213	Significant
Small	Estimated Length	High-Low	-4.4923	0.0002	0.0005	Significant
Small	Estimated Length	Medium-Low	-2.4791	0.0209	0.0213	Significant
Small	Estimated Distance	High-Medium	-1.4202	0.169	0.3249	Not Significant
Small	Estimated Distance	High-Low	-2.4907	0.0204	0.0612	Trending
Small	Estimated Distance	Medium-Low	-1.4433	0.1624	0.3249	Not Significant
Medium	Spaciousness	High-Medium	-4.4078	0.0002	0.0006	Significant
Medium	Spaciousness	High-Low	-4.0953	0.0004	0.0009	Significant
Medium	Spaciousness	Medium-Low	-0.3294	0.7448	0.7448	Not Significant
Medium	Estimated Width	High-Medium	-3.8251	0.0009	0.0026	Significant
Medium	Estimated Width	High-Low	-3.7951	0.0009	0.0026	Significant
Medium	Estimated Width	Medium-Low	-1.0491	0.305	0.305	Not Significant
Medium	Estimated Length	High-Medium	-0.49	0.6288	0.6288	Not Significant
Medium	Estimated Length	High-Low	-2.3214	0.0295	0.0884	Trending

Medium	Estimated Length	Medium-Low	-2.1096	0.046	0.092	Trending
Medium	Estimated Distance	High-Medium	-0.6837	0.501	0.501	Not Significant
Medium	Estimated Distance	High-Low	-2.472	0.0213	0.0638	Trending
Medium	Estimated Distance	Medium-Low	-2.008	0.0565	0.1131	Not Significant
Large	Spaciousness	High-Medium	-2.7896	0.0104	0.0104	Significant
Large	Spaciousness	High-Low	-5.6406	< .0001	< .0001	Significant
Large	Spaciousness	Medium-Low	-5.5293	< .0001	< .0001	Significant
Large	Estimated Width	High-Medium	-1.4091	0.1722	0.1722	Not Significant
Large	Estimated Width	High-Low	-2.5304	0.0187	0.0561	Trending
Large	Estimated Width	Medium-Low	-1.8507	0.0771	0.1542	Not Significant
Large	Estimated Length	High-Medium	-1.551	0.1346	0.2307	Not Significant
Large	Estimated Length	High-Low	-2.012	0.0561	0.1682	Not Significant
Large	Estimated Length	Medium-Low	-1.6365	0.1153	0.2307	Not Significant
Large	Estimated Distance	High-Medium	-1.215	0.2367	0.2367	Not Significant
Large	Estimated Distance	High-Low	-2.4798	0.0209	0.0627	Trending
Large	Estimated Distance	Medium-Low	-1.9275	0.0664	0.1327	Not Significant

Table C

Spatial Perception and Affective Response Comparisons Across Different Room Sizes Within Surface Absorption

Wall Material	*Variable*	*Comparison*	*t-Statistic*	*Raw P-Value*	*Corrected P-Value*	*Significance*
High	Pleasant	Small-Medium	-1.567	0.1308	0.3923	Not Significant
High	Pleasant	Small-Large	-1.3418	0.1928	0.3923	Not Significant
High	Pleasant	Medium-Large	0.0	1.0	1.0	Not Significant
High	Comfortable	Small-Medium	-2.6149	0.0155	0.0464	Significant

High	Comfortable	Small-Large	-1.8272	0.0807	0.1614	Not Significant
High	Comfortable	Medium-Large	0.5219	0.6067	0.6067	Not Significant
High	Safety	Small-Medium	-1.4364	0.1644	0.3287	Not Significant
High	Safety	Small-Large	-1.8946	0.0708	0.2124	Not Significant
High	Safety	Medium-Large	-0.9204	0.3669	0.3669	Not Significant
High	Anxiety	Small-Medium	2.635	0.0148	0.0296	Significant
High	Anxiety	Small-Large	3.2333	0.0037	0.011	Significant
High	Anxiety	Medium-Large	1.4302	0.1661	0.1661	Not Significant
High	Spaciousness	Small-Medium	-2.8732	0.0086	0.0172	Significant
High	Spaciousness	Small-Large	-3.202	0.004	0.0119	Significant
High	Spaciousness	Medium-Large	-0.8338	0.4129	0.4129	Not Significant
High	Estimated Width	Small-Medium	-1.2739	0.2154	0.2154	Not Significant
High	Estimated Width	Small-Large	-2.173	0.0403	0.0807	Trending
High	Estimated Width	Medium-Large	-2.4797	0.0209	0.0627	Trending
High	Estimated Length	Small-Medium	-2.6813	0.0133	0.04	Significant
High	Estimated Length	Small-Large	-2.0783	0.049	0.098	Trending
High	Estimated Length	Medium-Large	-0.4552	0.6533	0.6533	Not Significant
High	Estimated Distance	Small-Medium	-2.7457	0.0115	0.023	Significant
High	Estimated Distance	Small-Large	-3.4524	0.0022	0.0065	Significant
High	Estimated Distance	Medium-Large	-0.627	0.5368	0.5368	Not Significant
Moderate	Pleasant	Small-Medium	-1.9689	0.0611	0.1834	Not Significant
Moderate	Pleasant	Small-Large	-1.4624	0.1572	0.3143	Not Significant
Moderate	Pleasant	Medium-Large	0.1321	0.8961	0.8961	Not Significant
Moderate	Comfortable	Small-Medium	-3.0394	0.0058	0.0175	Significant

Moderate	Comfortable	Small-Large	-2.0487	0.0521	0.1041	Not Significant
Moderate	Comfortable	Medium-Large	0.9145	0.3699	0.3699	Not Significant
Moderate	Safety	Small-Medium	-3.0107	0.0062	0.0187	Significant
Moderate	Safety	Small-Large	-2.3251	0.0292	0.0585	Trending
Moderate	Safety	Medium-Large	1.115	0.2764	0.2764	Not Significant
Moderate	Anxiety	Small-Medium	3.3749	0.0026	0.0052	Significant
Moderate	Anxiety	Small-Large	4.8911	< .0001	0.0002	Significant
Moderate	Anxiety	Medium-Large	0.0	1.0	1.0	Not Significant
Moderate	Spaciousness	Small-Medium	-2.4495	0.0223	0.0486	Significant
Moderate	Spaciousness	Small-Large	-2.5948	0.0162	0.0486	Significant
Moderate	Spaciousness	Medium-Large	-0.1116	0.9121	0.9121	Not Significant
Moderate	Estimated Width	Small-Medium	-1.3415	0.1929	0.2012	Not Significant
Moderate	Estimated Width	Small-Large	-2.5221	0.019	0.0571	Trending
Moderate	Estimated Width	Medium-Large	-1.7108	0.1006	0.2012	Not Significant
Moderate	Estimated Length	Small-Medium	-1.0584	0.3009	0.3009	Not Significant
Moderate	Estimated Length	Small-Large	-3.354	0.0027	0.0082	Significant
Moderate	Estimated Length	Medium-Large	-2.4573	0.022	0.0439	Significant
Moderate	Estimated Distance	Small-Medium	-1.7775	0.0887	0.1774	Not Significant
Moderate	Estimated Distance	Small-Large	-3.6682	0.0013	0.0038	Significant
Moderate	Estimated Distance	Medium-Large	-1.1569	0.2592	0.2592	Not Significant
Low	Pleasant	Small-Medium	-1.664	0.1097	0.1747	Not Significant
Low	Pleasant	Small-Large	-3.4438	0.0022	0.0066	Significant
Low	Pleasant	Medium-Large	-1.7856	0.0874	0.1747	Not Significant
Low	Comfortable	Small-Medium	-1.9036	0.0695	0.1391	Not Significant

Low	Comfortable	Small-Large	-2.3869	0.0256	0.0768	Trending
Low	Comfortable	Medium-Large	-0.5084	0.616	0.616	Not Significant
Low	Safety	Small-Medium	-2.0244	0.0547	0.1094	Not Significant
Low	Safety	Small-Large	-2.3443	0.0281	0.0842	Trending
Low	Safety	Medium-Large	-0.5264	0.6036	0.6036	Not Significant
Low	Anxiety	Small-Medium	2.3979	0.025	0.05	Significant
Low	Anxiety	Small-Large	2.6543	0.0142	0.0425	Significant
Low	Anxiety	Medium-Large	-0.2248	0.8241	0.8241	Not Significant
Low	Spaciousness	Small-Medium	-1.3198	0.1999	0.1999	Not Significant
Low	Spaciousness	Small-Large	-7.5907	< .0001	< .0001	Significant
Low	Spaciousness	Medium-Large	-3.4701	0.0021	0.0041	Significant
Low	Estimated Width	Small-Medium	-1.8879	0.0717	0.0717	Trending
Low	Estimated Width	Small-Large	-3.8309	0.0009	0.0026	Significant
Low	Estimated Width	Medium-Large	-2.2566	0.0338	0.0677	Trending
Low	Estimated Length	Small-Medium	-2.0199	0.0552	0.1104	Not Significant
Low	Estimated Length	Small-Large	-2.324	0.0293	0.088	Trending
Low	Estimated Length	Medium-Large	-1.1223	0.2733	0.2733	Not Significant
Low	Estimated Distance	Small-Medium	-3.1638	0.0043	0.0087	Significant
Low	Estimated Distance	Small-Large	-4.5848	0.0001	0.0004	Significant
Low	Estimated Distance	Medium-Large	-0.7764	0.4454	0.4454	Not Si

Experiment Guide

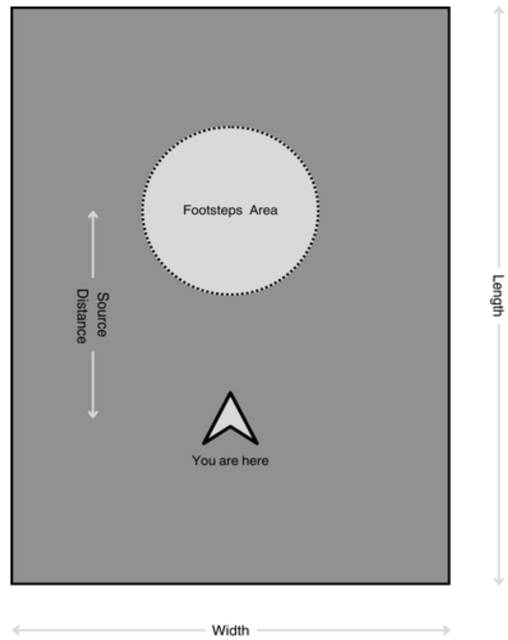
Thank you for participating in this study. In this experiment, we are exploring how people perceive different acoustic environments. You'll listen to a series of sound environments, each simulating the sound of footsteps in virtual rooms that vary in characteristics. To help guide your responses, we'll start with two introductory rooms before we continue with the main phase of the experiment. After each room is presented, you'll hear a set of questions, to which you can respond verbally. We ask you to read them carefully before we proceed to the experiment:

I. Width and Length

Q1: "What is the width of the room? Please give your estimate in meters"

Q2: "What is the length of the room? Please give your estimate in meters"

When we talk about the ***width***, we mean the distance between the walls to your ***left and right***. The ***length***, on the other hand, is the distance between the wall in ***front and behind*** you. Don't worry about being exact, just give your best estimate in meters.



II. Sound Source Distance

Q3: "How far are the footsteps from you? Please give your estimate in meters"

We would like you to estimate how far away the footsteps are from you.

When answering, think about the distance between yourself and the footsteps in front of you. Again, don't worry about being exact, just give your best estimate in meters.

III. Spaciousness

Q4: "How spacious is this room to you? 1 being not at all spacious and 9 being very spacious"

Spaciousness is the subjective sense of how much area there is to exist and move within a space. Your rating should reflect your impression, and there is no right or wrong answer.

IV. Experience

Q5: "How pleasant is your overall sonic experience? 1 being not pleasant at all and 9 being very pleasant."

Q6: "How comfortable do you feel in this room? 1 being not comfortable at all and 9 being very comfortable."

Q7: "How safe do you feel in this room? 1 being not safe at all and 9 being very safe."

Q8: "How anxious do you feel in this room? 1 being not anxious at all and 9 being very anxious."

Remember, there are no right or wrong answers; what matters most is your personal experience.

We encourage you to respond honestly based on your own impression of the moment. If at any time during this study, you become uncomfortable or simply wish to stop, you are free to end your participation immediately.