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SOUNDSCAPE EXPERIENCE MAPPING: A DEEP LISTENING APPROACH FOR ELICITING OLDER ADULTS' PERCEPTIONS OF INDOOR SOUNDSCAPES

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ABSTRACT

Indoor soundscapes significantly impact wellbeing, yet methodologies for understanding their perception among older adults remain underdeveloped. This paper presents Soundscape Experience Mapping (SEM), combining ecological momentary assessment with participatory design methods to capture and analyse indoor acoustic environments. Through structured listening activities and audio data collection, participants document their acoustic experiences in context.

Our pilot study engaged eight older adults (56+) in a town in Belgium, collecting continuous audio recordings and qualitative data over one week. Using momentary judgements, retrospective evaluations, and sound journalling, we gained insights into how older adults perceive their indoor soundscapes. The method produced findings on the personal control of sound environments, soundscape preferences, and how situational factors influence acoustic perception. Participants demonstrated agency in curating their sonic environments, while expressing frustration with uncontrollable sounds. Daily routines and domestic rhythms emerged as key contextual factors shaping soundscape experiences. This work advances AI-assisted indoor soundscape design by providing evidence-based methods to understand occupant needs, particularly for older adults who could benefit from tailored acoustic environments.

Keywords: indoor soundscape, older adults, wellbeing, deep listening, design methods

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1. INTRODUCTION

With the global population ageing at a rapid rate - the number of individuals aged 60 years and older is expected to increase by 34% between 2019 and 2030 [1] - creating appropriate sonic environments for older adults has become increasingly important. As more people choose to age in place and receive care in their homes [1], we face both a challenge and opportunity to enhance quality of life through the intentional design of supportive indoor acoustic environments.

Older adults typically spend more time at home. If those homes have poor acoustic conditions, this could exacerbate negative health outcomes including cardiovascular effects and sleep disturbance [2]. Research indicates that effective indoor acoustic environments must consider not just objective sound levels, but how environmental sounds are subjectively perceived by occupants [3]. Subjective perception matters for older adults who may process and experience sound differently than younger populations, with factors like age-related hearing loss and altered auditory processing needing to be accounted for [4]. But, methodologies designed to capture older adults' soundscape experiences remain underdeveloped. This lack of methods to understand age-specific soundscape needs represents an issue for developing acoustic design principles for this growing demographic.

Our Soundscape Experience Mapping (SEM) method addresses this issue by combining multiple research approaches to understand older adults' indoor soundscape needs. SEM engages participants in documenting and evaluating sonic experiences at home, supporting three aims: 1) develop a participatory methodology for capturing soundscape needs, 2) identify situational factors influencing these perceptions, and 3) establish design princi-

ples for AI-assisted soundscape technologies. By creating protocols to document relationships between acoustic preferences, activities, and emotional responses, we provide ways to develop supportive acoustic environments tailored to individual needs. In this paper we present findings from (a) soundscape judgement tasks, examining older adults' soundscape experiences; and (b) participant feedback data, providing insights into conducting home soundscape studies with older adults using our novel methods. The presented SEM methodology offers ways to gather insights for architects, designers, and researchers working to create more supportive acoustic environments for older adults.

2. BACKGROUND

We utilise the ISO definition of Soundscape [5], where soundscape is a perceptual construct describing how people perceive and understand their acoustic environment within context. Indoor soundscape research distinguishes how indoor environments can differ from outdoor ones [3]. Indoor environments offer greater potential for perceived control and predictability of sound—though this control is influenced by building design, ventilation systems, and occupant activities [6]. The capacity for control and predictability creates opportunities to design supportive acoustic spaces that enhance wellbeing — minimising unwanted sounds, amplifying desired sounds, and offering personalised control options.

Indoor soundscape assessment uses specific dimensions - like 'private and under-control' vs. 'intrusive and uncontrolled' [6] - to analyse relevant features of interior spaces. Likewise, situational factors — including location, activity, and social surroundings — influence soundscape perception [7]. Recent research is beginning to incorporate situational factors into the broader idea non-acoustic 'context' factors for the ISO standards [8]. We see situational factors in indoor soundscapes as particularly important for older adults who may have distinct acoustic preferences and needs [4].

Complementary methods are said to be effective for studying indoor soundscapes [9]. Ecological Momentary Assessment (EMA) uses smartphone prompts to capture real-time perceptions [10] and has previously shown connections between soundscapes, situational factors, and emotional responses [7]. From design research, home soundwalks can elicit reflections on room-specific experiences [11], while cultural probes [12] can encourage active sound engagement through activities like sound journalling and recording. Such approaches provide experiential data that can inform designers on how to create AI systems that will analyse and generate appropriate soundscapes. The success of such methods depends on designing activities that promote open-mindedness and exploration [12]. We focus on how EMA and design research methods can be combined to explore home soundscapes.

3. METHODOLOGY

3.1 Study Design and Implementation Details

This pilot study was conducted through a grant from the European Network of Living Labs VITALISE program to research AI-assisted home soundscape technologies for older adults. We worked with Living and Care Lab (LiCalab) in Geel, Belgium, who provided: recruitment and engagement from their existing user panel; access to participants' homes; expertise in conducting living lab studies; protocol and data translation support.

The study included 8 healthy older adults, who were aged between 56 and 76. The study took place in participants' homes located in Geel, Belgium and in co-creation sessions at LiCalab's facilities in Turnhout, Belgium. The study adhered to ethical protocols for human participant research with approval from required ethics boards (University of Surrey RIGO: FEPS 23-24 001 EGA, KU Leuven SMEC: G-2023 11 2174).

Initial work spanned 4 weeks from October to December 2023. An additional co-creation workshop was conducted in October 2024. Figure 1 shows the overall study timeline, with four participant engagement stages. This paper focuses on two stages: (2) The Home Deployment Phase (HDP) that includes Home Audio Recording, EMA, and Cultural Probe tasks; and (3) the debrief session that includes the Post-HDP Survey where we gathered participant reflections on their study involvement.

3.2 'Soundscape Experience Mapping' Approach

The Soundscape Experience Mapping (SEM) method combines activities that elicit creative interpretations of sound experiences and the systematic capture and analysis of naturally occurring indoor soundscapes. SEM employs in-home data collection with free-form descriptions that allow participants to use their natural language. In this section, we provide a condensed overview of the SEM approach, with only snapshots of all the pilot study elements. In the next section, we provide more detail on measures evaluated in this paper.

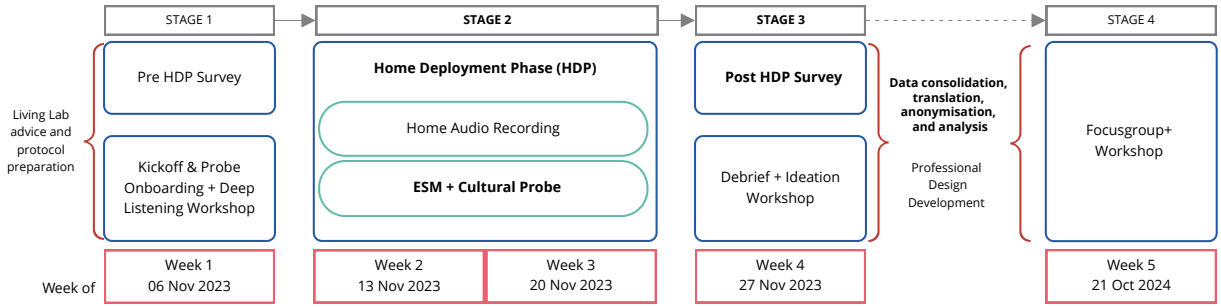

Figure 1. Four-stage living lab study timeline, conducted between November 2023 and October 2024. Areas covered in this paper highlighted with bold type.

Deep Listening Activities: To help participants listen deeply to their sound environments, we designed a set of EMA activities and bespoke materials (see Figure 2). For this, we merged practice from soundscape categorisation [13], deep listening [14], smartphone-based EMA [7, 10], and cultural probes [12]. To collect data we setup an EMA smartphone app for sound recording, speech/text journalling, and survey delivery, with notifications during the HDP phase. Design of soundscape assessments and participant labelling of sounds are described Section 3.3.

Applied Participatory Design for AI: Workshops and focus groups were conducted throughout the study, including onboarding, debrief, and co-creation activities. These sessions provided opportunities for gathering participant feedback, addressing ethical considerations, and enabling participants to shape project contributions. Analysis of this SEM component not discussed in this paper.

Home Audio Sound Event Detection Analysis: Seven-day continuous audio recording in participants' homes used two AudioMoth devices. We analysed audio recordings using sound event detection machine listening models to compare AI classifications with participant labelling. The resulting dataset and analysis is described in [15], analysis of this SEM component not discussed in this paper.

Reflexive Thematic Analysis: Thematic analysis [16] was used throughout the study to analyse qualitative data from participant responses and conversations. The analysis involved identifying, coding, and interpreting patterns of meaning within the data. Our approach was reflexive, acknowledging the researchers' roles and theoretical positions in shaping the analysis of participants' lived experiences [16].

Figure 2. Soundscape Experience Mapping kit given to participants containing instructions, craft materials, bespoke booklet, and AudioMoths.

3.3 EMA Soundscape Assessments

The SEM protocol collects complementary data types via different EMA listening tasks. This protocol aims to balance standardised measurement with participant-centred flexibility, to gather experiential data while minimising participant burden. We developed our assessment protocol by integrating ISO soundscape standards [5] with EMA approaches [7, 10]. We used validated Dutch/Flemish translations of soundscape attributes [17]. To reduce completion time and respondent fatigue [10], we combined soundscape dimensions onto semantic-differential scales. Soundscape assessments incorporated free-form descriptions, based on recommendations from Bones et al. [13], who demonstrated that spontaneously generated descriptive words yield categorisations different from predetermined scales.

A **Momentary Soundscape Judgements (MSJ)** task

provided real-time assessments triggered at set intervals throughout the week, where participants listened and recorded a 10-30s audio sample then rated their immediate acoustic environment on indoor soundscape semantic-differential scales, and responded to the following questions via voice note or text:

1. "Try to identify all the different sounds you could hear, describe these in whatever way you like."
2. "What is going through your mind? Write down your thoughts and feelings after listening to the environment."

A **Sound Journalling Task (SJT)** enabled self-initiated documentation of noteworthy sounds, allowing participants to record audio, take photos or videos of sound objects, and provide reflections about the meaningfulness of that sonic experience.

Both these listening tasks incorporated the Affective Slider [18] to measure arousal-valence dimensions of emotional response to soundscapes, and collected situational factors like location, activity, and social setting (alone/not alone).

This approach to soundscape assessment implements four recommendations from Bones et al. [13]: enabling natural language descriptions through free-form responses; eliciting emotional responses through open-ended questions; capturing valence-arousal dimensions to understand emotional impacts; and gathering contextual background about experiences influencing perception.

3.4 Open-source Methodology and Data

The complete bilingual protocol—including all listening tasks, prompts, and response formats—is available in our workflow supplement (`https://zenodo.org/records/14946672`). All anonymized data is available via the data supplements (`https://zenodo.org/records/14999348` and [15]).

3.5 Methodological Caveats

Our SEM approach and study results have several considerations that inform both interpretation of findings and future research. As a small-scale pilot with self-selecting participants (n=8), conducted only in homes in one region of Belgium, the findings have limited generalisability. Also, one-week data collection cannot capture seasonal variations in soundscape experiences and the October-December timing will influence indoor activities and ambient soundscapes.

4. RESULTS

4.1 Soundscape EMA Responses Qualitative Analysis

We review themes on how participants experienced indoor soundscapes via listening tasks. In presentation of participant data we use a coding system such as MSJ/SJT-XX-PY where MSJ/SJT is the task, XX is a unique data identifier for that task, and PX is the participant ID. The study collected 38 MSJ and 38 SJT responses.

4.1.1 Personal Control and Agency

Our older adult participants demonstrated agency (i.e. a person that acts to produce a particular result) in actively curating their sonic environments. This manifested through intentional selection and customization of soundscapes to match individual preferences. For instance, P3 deliberately chose a specific environment that provided comfort—they felt at ease in a busy café atmosphere because it was their choice to be there (SJT-23-P3). P3 also chose sounds for emotional benefits, such as selecting classical music for its ability to bring "peace in my head and also memories of the past" (SJT-32-P3). However, participants also expressed frustration with sounds they couldn't control. Industrial and transportation noises were particularly problematic, negatively impacting their sense of calm, peace, and ability to focus. Four responses (SJT-37-P6, MSJ-03-P6, MSJ-11-P6, MSJ-28-P4) expressed feelings of powerlessness over intrusive sounds in their daily lives, particularly regarding industrial noises, traffic, and mechanical sounds. This inability to escape or mitigate unwanted sounds that caused distress was noted across the thematic analysis (11 coded responses across 3 participants). Similar to previous research [3, 9], the SEM analysis shows that the perceived control of sound is linked to affective appraisal, suggesting that agency in sound management plays a role in older adults' wellbeing.

4.1.2 Acoustic Comfort and Environment Quality

Natural elements such as the sound of the wind or the crunch of leaves, were often associated with peace and comfort (10 responses across 5 participants). Similar to previous research on older adult preferences [4], music, particularly familiar pieces, created positive emotional experiences for P3 and P5. In contrast, participants express concern about noise pollution's impact on quality of life (MSJ-03-P6, MSJ-07-P6, MSJ-08-P3, MSJ-28-P4) with aircraft and traffic being particularly irritating and disrupting to the desired sense of peace and quiet. Specific sounds were noted as particularly bothersome, such

as "buzzing of the fridge, monotonous and sharp, annoying" (MSJ-11-P6) or "almost uninterrupted monotonous noise of passing vehicles" (MSJ-28-P4). However, everyday domestic sounds also contributed to a feeling of comfort and routine for some. For example, "the tapping (*tikken*) of wood burning and the gentle hum of the fridge" created "a home-like feeling of peace after a day's work" (MSJ-16-P6). Note the contradictions of P6 where fridge sound is experienced differently. This highlights the nuance required to understand individual preferences for indoor soundscapes, as mundane household sounds should not all be considered disturbances, at all times.

4.1.3 Situational Factors in Indoor Soundscape Experience

Our thematic analysis suggests that the way people felt about sounds changed depending on when and where they heard them. The same sound could be perceived as either positive or negative depending on the time of day, location, activity, or social setting. Below, two themes illustrate how context can shape our interpretation of sounds.

The **Sense of Place** theme highlights how sounds contribute to creating a sense of place and embody connections to specific environments. Soundscapes evoked emotional and psychological responses that are tied to particular places. For instance, the sound of a fire in a stove brings feelings of peace, warmth, and home-like comfort (MSJ-26-P5, SJT-18-P6). Certain sounds act as temporal markers, signalling specific times of day or transitions, such as people returning from work in the evening (MSJ-34-P5), contributing to the rhythm and character of a place. Additionally, sounds can trigger memories or associations with specific places or activities, such as rain signalling indoor activities or evoking childhood memories (MSJ-22-P6). This theme demonstrates how auditory experiences influence participants perception of their environment and their emotional connections to specific locations.

The **Patterns and Routines** theme marked how household sounds serve as both temporal markers and elements of domestic rituals. Throughout the day, specific appliances and activities act as acoustic anchors: coffee makers signal morning beginnings (SJT-18-P6), laundry cycles mark mid-day periods (SJT-07-P5), and evening transitions like the previous example from P6 where the "tapping of wood burning" and "gentle hum of the fridge" signal a "home-like feeling of peace after a day's work" (MSJ-16-P6). These sounds mark transitions between active and restful states while becoming deeply integrated into daily routines. Cooking activities emerged as recurring acoustic events, prompting both practical considerations and deeper reflections. Sounds like the steam cooker were "not so pleasant but necessary to be able to cook well" (SJT-05-P3) and certain participants accepted such sounds as essential parts of domestic life, sometimes expressing gratitude for modern conveniences: "it's nice to have my machine working for me" (SJT-07-P5).

4.1.4 Heightened Awareness and Reflection Through Deep Listening Tasks

The act of actively listening to, and reflecting on, sound prompted participants to engage with their environment more consciously. We noted five themes for this. **Listening to Details** marks where participants demonstrate non-trivial engagement with the sounds in their environment, often linking to causality or relationship e.g. "group of students arriving at the classroom, but first turning to a vending machine for drinks ... footsteps, drinking bus that clicks open, water that flows, group that moves back, some chatter to hear at a distance" (SJT-26-P7). **Acceptance**, where participants demonstrate acceptance of potentially disruptive or annoying sounds in their environment, such as the steam cooker example above (SJT-05-P3). **Taking A Moment** where participants describe how the act of listening consciously creates opportunities for pause, reflection, and appreciation of their surroundings. **Imaginative Listening** where participants engage with sounds in poetic, creative, or imaginative ways e.g. "Crackling, chasing, splashing. Nice, brings peace, warmth. Beautiful glow. The fire in the stove" (MSJ-26-P5). These ideas suggest that the SEM listening tasks support phenomenological engagement in sonic surroundings in novel ways.

4.2 Participant Feedback on Stages 1-3 of SEM Approach

We gathered feedback from participants in a *Post HDP Survey* using the following questions: (1) *What aspects of participating did you enjoy most?* (2) *How did the study affect your wellbeing, if at all?* (3) *What challenges did you encounter during the study?* (4) *Describe one optional activity you completed.* (5) *How did the study influence your listening and sound awareness?* (6) *How did you feel about having recording equipment at home? Did it affect your behaviour?* (7) *What improvements would you suggest for the EMA app?* (8) *Do you have other comments to share?*
Quotes reported below are indicated by participant ID and

Table 1. Summary of Participant Feedback Themes

Theme	Findings
Enhanced Sound Awareness	• Improved environmental sound awareness (P2, P4, P7) • Shift from negative to positive sound focus (P2, P8) • Greater appreciation for silence and nature (P2, P5, P8)
Wellbeing and Growth	• Positive impacts through sound awareness (P2, P4, P5) • Self-discovery opportunities (P5, P6, P8) • Activities provided valuable distraction to pain (P5)
Technical Challenges	• Navigation issues with EMA app interface (P1, P2, P4) • Need for simpler instructions (P4, P5) • Recording functionality issues (P2, P7)
Recording Device Impact	• Initial temporary discomfort (P2, P3, P6) • Behavioural changes during conversations (P6, P8) • Minimal device awareness for some (P1, P4)
Social Aspects	• Valued social elements (P3, P8) • Desire for group activities (P6, P8) • Important researcher interactions (P3, P5)
Study Structure	• Intensity after several days (P3) • More thoughtful responses over time (P8) • Timing improvements needed (P4, P7)

question response source e.g. (P1:Q3).

4.2.1 Feedback Themes

As shown in Table 1, participant feedback is grouped into six themes. Participants reported, that they: had a tendency to notice and appreciate environmental sounds that they previously overlooked, experienced positive impact on mental wellbeing through mindful sound engagement, struggled with technical aspects of the mobile app interface, felt varying degrees of comfort with recording devices in their homes, valued social connections made during the study, had issues with EMA task timing and engagement that could improve future implementations. Next, we only review study engagement and experience related themes in detail, as it provides evidence for the methodological contribution of the SEM approach.

4.2.2 Participant Engagement and Experience

Reviewing both positive and negative aspects of participants' experiences in the pilot study we found perceptions of the study's value, how engaging and insightful they found it, and the overall impact on their understanding of sound and their environment. Relevant aspects include: feelings of enjoyment, inspiration, increased awareness, and any negative experiences such as stress or frustration.

Participant engagement and experience was largely positive. Participants found the study "fun" (P2:Q1, P5:Q1), "challenging" (P2:Q3, P6:Q1), and "inspiring" (P6:Q1), and a source of "curiosity" (P5:Q1) and was informative (P3:Q1). Increased awareness of environmental sounds and a heightened appreciation for silence were reported (P2:Q1,P6:Q1,P7:Q1).

The unconventional nature of the activities fostered sonic engagement among participants. P2 described discovering their environment through "a new angle (hearing)" that broadened perception by "complementing the visual with more focused attention to sounds" (P2:Q1). P4 noted each assignment required applying oneself "totally differently (than in ordinary life)" (P4:Q3). P5 experienced a perceptual shift where "ordinary sounds were suddenly fun" (P5:Q3), and another emphasised how the protocol encouraged deliberate focus on "actions that produce sound and then listening in detail" (P7:Q1). These responses demonstrate how structured listening activities can transform everyday auditory experiences into meaningful engagement with everyday soundscapes.

However, feedback also reveals negative experiences. The EMA app's interface and the sheer volume of materials were criticised by some participants (P4:Q1, P4:Q7, P2:Q7). For one participant, the study's intensity, with the timing of EMA notifications, lead to anxiety (P4:Q3). The task of making sound recordings proved challenging for one participant, particularly the timing of the EMA notification was linked to difficulty in being able to record what they wanted (P2:Q4).

5. DISCUSSION

Our findings demonstrate that the SEM approach can capture aspects of the nuanced and contextual nature of indoor soundscapes for older adults. Through participant reflections and engagement activities, we developed themes about how sound interacts with daily routines, emotional states, and perceptions of place. The combination of ecological momentary assessment with deep listening practices enabled an analysis of how soundscapes contribute to comfort, wellbeing, and sense of home.

It is important to note that the results presented here are summarised and do not aim to examine concepts in exhaustive detail. Rather, these findings serve as illustrative examples to demonstrate the value and potential of the SEM approach in capturing rich, contextual data about indoor soundscapes for older adults. The selected participant responses highlight how this methodological approach enables the collection of nuanced perspectives that might be missed through traditional laboratory studies or standardised questionnaires alone. These selected findings demonstrate the methodological contribution of combining ecological momentary assessment with deep listening practices.

Looking across activities at participants' subjective responses to sound, we show the individuated ways people perceive and reflect on their sound environments. Participants' reflections highlight the interplay between the objective characteristics of sound, personal experiences and memories, and emotional responses. This connects with current research on non-acoustic factors in soundscapes [8], but specifically for the context of indoor soundscapes rather than outdoor environments.

6. METHODOLOGICAL IMPROVEMENTS

Analysis of the pilot study data revealed variable participant response rates for the MSJ task, with completion counts ranging from 1 to 9 entries per person (total: 38 MSJ, median: 5). This variability in responses highlights a key methodological challenge: the need to balance comprehensive data collection with participant engagement.

Based on feedback on the SEM approach, we recommend allowing participants to choose their preferred number of daily EMA activities and scheduling times, with the option for additional voluntary submissions. Furthermore, reducing the variety of tasks available across the whole SEM method is advised, as the full protocol had many elements.

More broadly for the field of indoor soundscapes, we see value in further implementing other recommendations from soundscape categorisation research [13]. Firstly, to incorporate multimodal cues that encourage participants to note all embodied and contextual cues that they rely on when describing sounds. This could help identify varying categorisation strategies across different sound types, to be compared across groups (e.g. hearing, housing type). Second, we would explore an iterative feedback loop where participants review their own categorisations and responses. This feedback loop may reveal deeper insights into their perception and associative processes.

7. CONCLUSION

In this paper, we have introduced the Soundscape Experience Method (SEM) and demonstrated its effectiveness in capturing indoor soundscapes for older adults through a combination of ecological momentary assessment with deep listening practices. Our pilot study with eight participants validated the method's ability to reveal how sound interacts with daily routines, emotional states, and perceptions of place, as evidenced by the high engagement rates and rich qualitative data collected. SEM addresses the need for contextually relevant indoor soundscape data and provides researchers with a framework to investigate acoustic experiences in homes. Through participant feedback and analysis of listening tasks, we have shown that the methodology successfully captures both immediate responses and reflective insights that laboratory studies could miss. The findings connect to existing literature, demonstrating the method's relevance while offering nuanced insights into participants' lived experiences. By combining audio recording, EMA, and cultural probes, we establish a foundation for designing more inclusive acoustic environments for older adults.

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