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# MEMORY RETRIEVAL IN URBAN AND INDOOR SOUNDSCAPES: AFFECTIVE AND COMFORT ASSOCIATIONS FROM SOUNDWALKS IN BRAZIL AND GERMANY

Margret Sibylle Engel[1], Marcos Holtz[2], Thomas Beckenbaur[3], M. Ercan Altinsoy[1]

[1]*Chair of Acoustics and Haptics, Dresden University of Technology, Germany*
[2]*University of São Paulo, São Paulo, Brazil*
[3]*ALD – German Society of Acoustics, Berlin, Germany*



## Abstract

Memory retrieval is closely tied to emotional and affective content. Prior research has shown that emotionally charged stimuli enhance recall and shape the subjective quality of remembered experiences. In the context of soundscapes, everyday acoustic environments can act as powerful cues for evoking autobiographical memories that are often intertwined with perceptions of comfort and affective appraisal. This study investigates memory retrieval in urban and indoor soundscapes, focusing on associations with affective and comfort attributes derived from soundwalk methodologies conducted in Brazil and Germany. In Brazil, data were collected at Inter-Noise 2025 with 35 participants, who evaluated two contrasting outdoor environments: a busy avenue and a quiet square. In Germany, data were gathered with 20 participants during DAGA 2026, covering two indoor areas within a conference venue and one outdoor area characterised by traffic noise and social interaction. Participants assessed affective and comfort-related attributes, as well as provided classified responses regarding emotions, preferences (like/dislike), appropriateness, and overall feeling. Reported memories were categorised and analysed in relation to these perceptual dimensions. Using correspondence analysis, associations were identified between specific types of retrieved memories, comfort attributes, and affective attributes. The results highlight systematic relationships between soundscape characteristics, affective-comfort evaluation, and memory content, suggesting that both environmental context and perceptual appraisal influence the nature of memory retrieval. These findings contribute to a deeper understanding of how urban and indoor acoustic environments support emotionally grounded memory processes, informing sound design strategies that promote comfort and positive experiences.

***Corresponding author**: margret.engel@mailbox.tu-dresden.de.*


**Keywords**: *Memory retrieval, Urban soundscapes, Indoor soundscapes, Affective attributes, Comfort attributes.*

## 1. Introduction

Existing studies have generally examined different forms of memory in isolation, most often within cognitive science [1] or narrative-based approaches that focus on collective memory [2]. Yet this separation does not reflect everyday experience, where different forms of memory are often activated simultaneously through sensory encounters. This phenomenon is particularly evident during soundwalks, where participants frequently recall personal experiences, shared histories, and contextual knowledge in response to the surrounding acoustic environment. Recent research further suggests that soundwalks facilitate memory retrieval by both evoking recollections and serving as repositories of personal and collective memory [3]. These findings point to the need for a more integrated understanding of memory in soundscape research, one that acknowledges the interplay between different memory systems as they are experienced in situ.

Regarding indoor environments, recent studies have shown that mechanical sounds and traffic noise are associated with impaired memory retrieval [4]. At the same time, indoor soundscapes can evoke autobiographical memories, prompting vivid recollections of participants' past experiences. These memories are often shaped by their emotional resonance, eliciting feelings of comfort, nostalgia, or, in some cases, negative reminiscence [5].

Based on this background, this study investigates how memory retrieval in urban and indoor soundscapes is influenced by a range of perceptual variables. The analysis is based on data collected during soundwalks conducted at Inter-Noise 2025 in predominantly outdoor environments and at DAGA 2026, which focused mainly on indoor settings. In addition to participants' reported memories, data were collected on perceptions of the location, liked and disliked aspects of the area, appropriateness, affective and comfort attributes, and emotional responses classified according to the frameworks of Plutchik and Russell. These variables were analysed together with memory retrieval using

correspondence analysis to explore their underlying associations.

## 2. Methods

### 2.1 Data collection

Data collection occurred during soundwalks conducted at Inter Noise 2025 in São Paulo, Brazil, at the end of August 2025, and at the German Society of Acoustics annual meeting DAGA 2006, held in March 2026 in Dresden, Germany. The soundwalks at both conferences aimed to collect data for scientific purposes, disseminate good methodological practices, and raise awareness about the topic of soundscapes.

### 2.2 Study areas

São Paulo is a megapolis in the southeast region of Brazil, as indicated in Figure 1. It has an estimated population of 11.9 million inhabitants within city limits and 21.4 to 23 million inhabitants in the metropolitan region [6]. The soundwalks in São Paulo took place in the neighbourhood of the WTC Events Centre & Sheraton WTC Hotel, in the Brooklin Novo quarter. Brooklin Novo is a modern, upscale neighbourhood in São Paulo's Southwest Zone, located in the Itaim Bibi district and known for its mix of financial activity and residential living [7]. As observed in Figure 1, the soundwalks started in front of the WTC Events Centre & Sheraton WTC Hotel (P1). The site is in an area characterised by high traffic volumes and noise, owing to its proximity to Av. das Nações Unidas, a major urban arterial roadway in São Paulo that runs parallel to the Marginal Pinheiros. In contrast, the second evaluation spot (P2) was at Arlindo Rossi Square by Cidade Monções/Itaim Bibi district, a quiet local green space surrounded by vegetation and residential buildings. The square had benches and a playground.

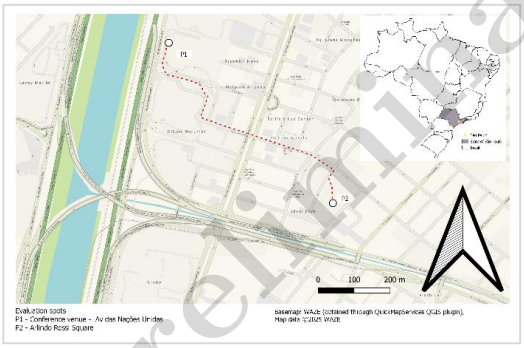


**Figure 1**. Soundwalks in São Paulo, Brazil.

The soundwalks in Dresden, a mid-size city (560,000 inhabitants) in east Germany, were conducted at the Maritim Hotel and the International Congress Centre Dresden (ICD) (Figure 2). Due to weather conditions, two of the three evaluation spots were located indoors, while the third was situated outside the conference venue. Evaluation Spot 1 was positioned in front of the conference registration area, where high pedestrian traffic, combined with reflective surfaces such as the pavement and surrounding windows, contributed to elevated sound levels. As this location was assessed at the beginning of the lunch break, conversations and foot traffic further increased the ambient noise. Evaluation Spot 2 was located outside the seminar rooms, where carpeted flooring helped dampen footstep noise, resulting in a quieter acoustic environment, although the area was relatively dimly lit. Evaluation Spot 3 was situated at the main entrance to the conference venue, outside the building, where traffic noise from nearby roads mixed with conversations among conference attendees. Despite these sound sources, the elevated location provided fresh air from the breeze and an open view of the Elbe River, contributing positively to the overall environmental experience (Figure 3).

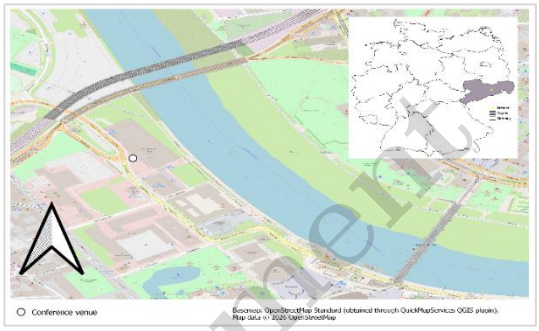


**Figure 2.** Soundwalk location in Dresden, Germany.

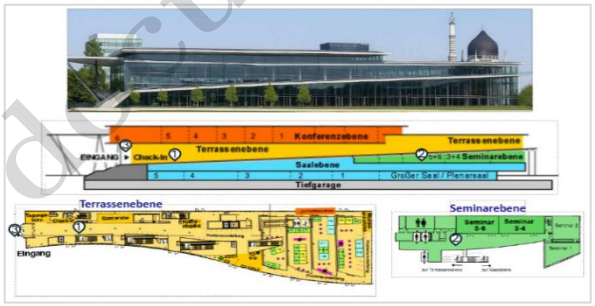


**Figure 3.** Evaluation spots inside the conference venue in Dresden. Source: Adapted from Maritim Hotel & International Congress Centre Dresden (ICD) [8]

### 2.3 Recruitment of participants

For Inter-Noise 2025, participants were recruited through the conference website, where they could register for the "IN25 Soundwalk" alongside other conference activities. The soundwalk was also promoted through the PróAcústica marketing newsletter distributed in connection with the conference programme. Similarly, for DAGA 2026, the soundwalk activities were announced in the conference programme, on the conference website, and in the conference booklet. For both conferences, pre-registration was recommended to facilitate planning, with a maximum capacity of 40 participants per soundwalk, including the 2–3 members of the soundwalk facilitation team.

### 2.4 Audiovisual recordings

During the soundwalks in both study areas, an Insta 360 X3 camera, a binaural microphone set (Squadriga III) from HEAD acoustics, a ZOOM H6 Essential recording device, and an Ambeo VR ambisonics microphone from Sennheiser, together with two tripods, were used for audiovisual data collection.

### 2.5 Subjective data collection

In the Inter Noise soundwalks, subjective data were collected through a Google Forms questionnaire, which participants accessed via a QR code. The questions were formulated in English, but a Portuguese version was also available for Brazilian attendees.

At DAGA 2026, the same Google Forms questionnaire was used, and a paper version was offered, but all participants preferred to respond in paper format. English and German versions of the questions were available for international and German attendees.

Before answering the questions, participants had to acknowledge the consent statement. The questions followed the format of ISO/TS 12913-2 [9], and complementary questions were added to assess preferences, emotions and memories [10]. Additional demographic questions were added to characterise the participant's profile (age, gender, field of study/work, nationality and hometown).

1) How do you feel about the overall physical environment in this area? (open-ended)
2) What do you like and dislike in this area? (open-ended) [10].
3) Overall, to what extent is the present surrounding sound environment appropriate to the present place? (5-point scale from 'not at all' to 'perfectly')
4) For each scale below, to what extent do you agree or disagree that the present surrounding sound environment is...Attributes: pleasant, chaotic, vibrant, uneventful, calm, annoying, monotonous, quiet, uncomfortable, comfortable, not annoying, noisy, exhausting and relaxing (scale: 'strongly agree', 'agree', 'neither agree nor disagree', 'disagree', 'strongly disagree')
5) To what extent do you presently hear the following four types of sounds? Sound sources: 'mechanical sounds', 'human sounds', 'natural sounds' (scale: 'not at all', 'a little', 'moderately', 'a lot', 'dominates completely').
6) Does the soundscape evoke any emotions? If yes, which ones? (open-ended) [10, 11].
7) Does the soundscape evoke any memories? If yes, which ones? (open-ended) [10].

### 2.6 Post-processing of the collected subjective data

For post-processing, the subjective data were classified, coded, curated, and organised into a matrix for posterior statistical analysis.

Regarding answer classification, the open-ended questions were classified into response groups using a hybrid deductive-inductive thematic approach [12] for questions 1 and 2, while for questions 6 and 7, a deductive approach was used. Question 1 was related to how the participant felt about the overall environment. The answers were classified initially using the framework suggested for landscape classification by Engel [10]. However, some adaptations were allowed, so the following classes were considered: 'Noise & Acoustic Conditions (Sense)', 'Crowding, Density & Movement (Cultural Social)', 'Comfort -physical environment (Sense)', 'Spatial Design & Architecture (Aesthetics)', 'Affective (Emotional/Evaluative) (Internal Factors)', 'Outdoor- Environmental Conditions (Natural)' and 'No, none, not applicable'. Question 2 asked what the participant liked and disliked in the area. The following classes were considered 'View, Nature & Outdoor Qualities (Natural)', 'Acoustic Comfort & Quietness (Sense)', 'Comfort, Coziness & Atmosphere (Aesthetic)', 'Spatial Design & Architecture (Aesthetic)', 'Light, Openness & Brightness (Sense)', 'Social & Activity-Related Qualities (Cultural Social)', 'Sensory Qualities (non-acoustic: wind, temperature, etc.) (Sense)', 'Material (Aesthetic)', and 'No / None / Not Applicable'. Question 6 about evoked emotions followed the classification of Engel et al. [11], which is based on Plutchik (1980) and Russel (1980) and correlations with psychoacoustic modelling. Question 7 was about retrieved memories. The answers were classified according to the framework suggested by Engel and Altinsoy [13], with the following memory classes: 'autobiographical', 'collective and cultural', episodic', 'semantic', and 'embodied or sensory'.

### 2.7 Statistical analysis

A correspondence analysis was conducted in IBM SPSS v. 29, using only the responses to Question 7 that described, recalled, or categorised reported memories; this variable was designated as the 'memories' parameter. The remaining parameters were derived from Questions 1–6 and were analysed pairwise in relation to the 'memories' parameter. The analysed variables included: location**;** overall feeling about the physical environment**;** liked area**;** disliked area**;** appropriateness**;** attributes (pleasant, chaotic, vibrant, uneventful, calm, annoying, eventful, monotonous, quiet, uncomfortable, comfortable, not annoying, noisy, exhausting, relaxing); sound sources (mechanical, human, natural); and emotions, based on the Plutchik and Russell models.

Psychoacoustic modelling used the same models as in Engel et al. [11] and provided the proportion of each psychoacoustic indicator for each evaluation spot.

## 3. Results

### 3.1 Demographics

A total of 35 individuals participated in the soundwalks conducted at Internoise 2025, including 22 (62.9%) females, 12 (34.3%) males, and 1 (2.9%) participant identifying as another gender. Participants ranged in age from 20 to 71 years (M = 38.97, SD = 13.62).

The DAGA 2026 soundwalks included 20 participants, comprising 14 (70.0%) males and 6 (30.0%) females. Their ages ranged from 20 to 82 years (M = 42.35, SD = 18.06).

Across both soundwalks, a total of 55 participants took part: 28 (50.9%) females, 26 (47.3%) males, and 1 (1.8%) participant identifying as another gender. Participants' ages ranged from 20 to 82 years, with a mean of 40.53 years (SD = 15.85).

### 3.2 Psychoacoustic modelling

The selected sites in São Paulo exhibited higher values for both the acoustic and psychoacoustic indicators than those in Dresden, with the largest differences observed at P1 (busy street). The lowest values were recorded at P3 in Dresden, corresponding to the site located at the entrance to the conference venue.

**Table 1**. Psychoacoustic modelling results

| Avg | P1 IN25 | P2 IN25 | P1 DAGA26 | P2 DAGA26 | P3 DAGA26 |
|---|---|---|---|---|---|
| SPL [dB] | 82.44 | 70.02 | 60.05 | 55.25 | 45.69 |
| SPLA [dB(A)] | 71.9 | 59.33 | 55.35 | 50.89 | 40.64 |
| Loudness [GFsone] | 27.97 | 12.95 | 8.23 | 6.19 | 2.86 |
| Loudness N5 [GFsone] | 37.21 | 15.3 | 10.22 | 7.86 | 4.55 |
| Sharpness [acum] | 1.1 | 1.11 | 1.18 | 1.06 | 1.17 |
| Roughness [asper] | 0.31 | 0.20 | 0.14 | 0.15 | 0.07 |
| F. Strength [vacil] | 0.0135 | 0.0085 | 0.01083 | 0.013 | 0.01156 |
| Tonality HM [tuHM] | 0.46 | 0.13 | 0.15 | 0.14 | 0.08 |

### 3.3 Descriptive analysis

Approximately 30% of participants in both soundwalks reported no memory retrieval. The remaining 70% of responses were distributed across five memory categories. In DAGA 2026, semantic (knowledge-based) memories were the most frequently retrieved (30%), followed by episodic (event-based) memories (15%). In contrast, autobiographical memories were the most frequently reported in Internoise 2025 (21.4%), followed by episodic (event-based) memories (15.7%) (Figure 4).

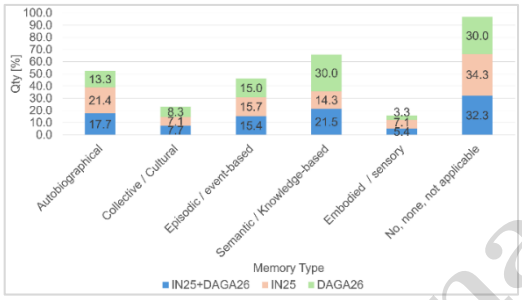


**Figure 4.** Type of memories distribution

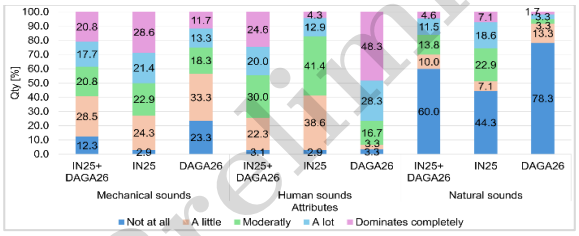


**Figure 5**. Sound sources ratings

Across the three sound source categories, human sounds were perceived as the most dominant, with nearly half of DAGA26 respondents (48.3%) and a small share of IN25 respondents rating them as prevalent or dominating, while mechanical sounds showed a more balanced, moderate distribution across response categories with some variation between subgroups in IN25. In DAGA26 subgroups, there was little or no perception of mechanical sounds. Natural sounds, by contrast, were overwhelmingly rated as "not at all" present, up to 78.3% in DAGA26 and 44.3% in IN25 (Figure 5).

### 3.4 Correspondence analysis

A Correspondence Analysis (CA) was used to examine the association between Memories (autobiographical, collective/cultural, episodic, semantic, embodied/sensory) and a set of soundscape and contextual variables, analysed separately for the Internoise 2025 (IN25) soundwalks, the DAGA 2026 (DAGA26) soundwalks, and the combined IN25+DAGA26 dataset.

As observed in Table 2, in IN25, four variables showed statistically significant associations with Memories: Not annoying, Exhausting, Relaxing, and Calm ($\chi^2(16)$ ranging from 26.36 to 30.18, p ranging from .017 to .049), with total inertia ranging from 0.573 to 0.656 and two-dimensional solutions capturing 84.8–98.6% of inertia. Notably, Relaxing and Calm were significant only at a borderline level (p = .049) and should be interpreted with caution.

In DAGA26, no statistically significant associations were found between Memories and any of the tested variables (all p > .05). This is likely attributable to the smaller sample size of the DAGA26 subset (n = 20 across three evaluation spots) relative to IN25 (n = 35 across two spots) and the combined dataset, reducing statistical power to detect associations that emerged when data were pooled or examined within the larger IN25 sample alone.

In the combined dataset (IN25+DAGA26), seven variables showed statistically significant associations with Memories: Location, Pleasant, Comfortable, Not_annoying, Noisy, Exhausting, and Relaxing ($\chi^2(16)$ ranging from 28.89 to 39.39, all p < .05), with total inertia ranging from 0.328 to 0.448 and two-dimensional solutions capturing 87.2–97.6% of inertia.

Across all significant analyses (Table 3), a recurring structural pattern was observed: Autobiographical, Episodic, and (in most cases) Embodied/sensory memories were consistently opposed to Collective/Cultural and/or Semantic memories along Dimension 1. This contrast replicated across both IN25 and the combined dataset, and across multiple independent soundscape variables (Not annoying, Exhausting, Relaxing), supporting its robustness as a genuine pattern rather than an artefact of any single analysis. Dislike area, significant in the combined dataset ($\chi^2(20) = 35.85$, p = .016), produced a degenerate solution due to severe category sparsity (two categories with n = 1 and n = 2) and was excluded from substantive interpretation.

No significant associations were found for Feel overall physical environment, Like area, Appropriateness, Chaotic, Vibrant, Uneventful, Annoying, Eventful, Monotonous, Quiet, Uncomfortable, Mechanical sounds, Human sounds, Natural sounds, Emotions Plutchik, or Emotions Russell in any of the three datasets.

## 4. Discussion

The absence of significant associations in the DAGA26 subset alone is most plausibly attributable to its limited sample size (n = 20, distributed across three evaluation spots) combined with the fact that this dataset was collected predominantly in an indoor setting, at the conference venue in Dresden.

**Table 2.** Correspondence Analysis results for Inter-Noise (IN25), DAGA (DAGA26) and combined datasets (IN25+DAGA26). Legend: Not significant (n.s.).

| Variable | Dataset | $\chi^2$ (df) | p | Total Inertia | Dim 1 % | Dim 2 % | Cumulative % | Significant? |
|---|---|---|---|---|---|---|---|---|
| Location | IN25+DAGA26 | 32.71 (16) | 0.008 | 0.372 | 69.50% | 27.30% | 96.80% | Yes |
| | IN25 | — | n.s. | — | — | — | — | No |
| | DAGA26 | — | n.s. | — | — | — | — | No |
| Pleasant | IN25+DAGA26 | 30.54 (16) | 0.015 | 0.347 | 75.50% | 22.10% | 97.60% | Yes |
| | IN25 | — | n.s. | — | — | — | — | No |
| | DAGA26 | — | n.s. | — | — | — | — | No |
| Comfortable | IN25+DAGA26 | 39.39 (16) | <.001 | 0.448 | 59.80% | 27.30% | 87.20% | Yes |
| | IN25 | — | n.s. | — | — | — | — | No |
| | DAGA26 | — | n.s. | — | — | — | — | No |
| Not annoying | IN25+DAGA26 | 34.36 (16) | 0.005 | 0.39 | 69.00% | 27.50% | 96.50% | Yes |
| | IN25 | 30.18 (16) | 0.017 | 0.656 | 64.60% | 34.10% | 98.60% | Yes |
| | DAGA26 | — | n.s. | — | — | — | — | No |
| Noisy | IN25+DAGA26 | 33.98 (16) | 0.005 | 0.386 | 67.20% | 21.30% | 88.50% | Yes |
| | IN25 | — | n.s. | — | — | — | — | No |
| | DAGA26 | — | n.s. | — | — | — | — | No |
| Exhausting | IN25+DAGA26 | 28.89 (16) | 0.025 | 0.328 | 59.50% | 30.40% | 90.00% | Yes |
| | IN25 | 27.60 (16) | 0.035 | 0.6 | 62.10% | 22.70% | 84.80% | Yes |
| | DAGA26 | — | n.s. | — | — | — | — | No |
| Relaxing | IN25+DAGA26 | 31.76 (16) | 0.011 | 0.361 | 69.60% | 21.30% | 90.90% | Yes |
| | IN25 | 26.36 (16) | 0.049 | 0.573 | 86.40% | 8.30% | 94.70% | Yes (borderline) |
| | DAGA26 | — | n.s. | — | — | — | — | No |
| Calm | IN25+DAGA26 | — | n.s. | — | — | — | — | No |
| | IN25 | 26.39 (16) | 0.049 | 0.574 | 63.00% | 34.80% | 97.80% | Yes (borderline) |
| | DAGA26 | — | n.s. | — | — | — | — | No |
| Dislike area | IN25+DAGA26 | — | n.s. | — | — | — | — | No |
| | IN25 | 35.85 (20) | 0.016 | 1.28 | — | — | — | Degenerate — excluded |
| | DAGA26 | — | n.s. | — | — | — | — | — |
| Feel overall physical env, Like area, Appropriateness, Chaotic, Vibrant, Uneventful, Annoying, Eventful, Monotonous, Quiet, Uncomfortable, Mechanical sounds, Human sounds, Natural sounds, Emotions Plutchik, Emotions Russell | All three | — | n.s. | — | — | — | — | No |

Table 3. Dimension 1 scores for 'Memories' compared to other variables, significant cases.

| Analysis | Autobiographical | Episodic | Embodied/sensory | Collective/Cultural | Semantic |
|---|---|---|---|---|---|
| Pleasant (IN25+DAGA26) | −0.355 | −0.479 | −1.189 | 1.534 | 0.383 |
| Location (IN25+DAGA26) | 0.779 | 0.084 | 1.177 | −0.932 | −0.661 |
| Noisy (IN25+DAGA26) | 0.687 | 0.168 | 1.197 | −1.228 | −0.545 |
| Comfortable (IN25+DAGA26) | -0.772 | -0.639 | 0.088 | 0.726 | 0.81 |
| Not annoying (IN25+DAGA26) | -0.644 | 0.801 | -0.089 | 0.688 | -1.527 |
| Exhausting (IN25+DAGA26) | −0.554 | −0.499 | −0.588 | 1.344 | 0.478 |
| Relaxing (IN25+DAGA26) | −0.806 | −0.287 | −0.758 | 0.975 | 0.708 |
| Exhausting (IN25) | −0.751 | −0.545 | 0.503 | 1.256 | 0.847 |
| Not annoying (IN25) | −0.610 | −0.283 | −0.921 | 1.316 | 1.028 |
| Relaxing (IN25) | −0.679 | −0.583 | −0.213 | 1.471 | 1.032 |
| Calm (IN25) | −0.699 | −0.495 | 0.232 | 0.372 | 1.291 |

This contrasts with the IN25 soundwalks, which were conducted outdoors across the evaluated locations, and may reflect a more homogeneous or context-constrained set of soundscape experiences within DAGA26, further

reducing the variability needed to detect associations with an already small sample.

Despite this lack of standalone significance, the DAGA26 data made a meaningful contribution when combined with IN25: several associations that were not significant in IN25 alone (Location, Pleasant, Comfortable, Noisy) became significant in the combined IN25+DAGA26 dataset. Beyond simply adding statistical power through a larger N, the inclusion of DAGA26 appeared to sharpen the structure of the correspondence analysis solutions themselves; in the combined dataset, Dimension 1 more frequently and more cleanly recovered the ordinal structure of the rating scales. This suggests that the indoor DAGA26 responses introduced a distinct range of soundscape–memory associations that, when pooled with the outdoor IN25 data, helped more clearly differentiate the underlying dimensions, rather than simply reinforcing the same pattern with more data points. This has a practical implication for interpreting the combined-dataset results. Rather than treating IN25+DAGA26 as a homogeneous sample, the significant findings may partly reflect the contrast between indoor and outdoor contexts captured across the two datasets. Future analyses could explicitly test this by including Dataset (or indoor/outdoor context) as a supplementary variable in the correspondence or multiple correspondence analysis, to clarify how much of the combined-dataset structure is driven by this contextual contrast [13] versus a genuinely shared association pattern across settings.

## 5. Conclusions

Across the outdoor soundwalks (IN25) and the combined outdoor-indoor dataset (IN25+DAGA26), a consistent pattern emerged: Autobiographical, Episodic/event-based, and in most cases Embodied/sensory memories were associated with more positively-evaluated soundscape qualities (greater pleasantness, comfort, relaxation, and calmness, and lower annoyance and exhaustion) while Collective/Cultural and Semantic/Knowledge-based memories were associated with the less favorably rated end of these same dimensions. This pattern held specifically for the outdoor IN25 environments (Not annoying, Exhausting, Relaxing, Calm) and was reinforced in the combined dataset, where it extended to additional variables (Location, Pleasant, Comfortable, Noisy).

For the indoor DAGA26 setting specifically, no significant standalone associations were found between Memories and any soundscape variable, so no independent conclusion can be drawn about which memory types characterise indoor soundscape evaluations on their own. However, the fact that adding this indoor data to the outdoor data sharpened the associations observed in the combined dataset suggests that indoor and outdoor contexts may evoke a different balance or expression of these memory types — with the outdoor environment more clearly favoring sensory and personally-lived memories (autobiographical, episodic, embodied/sensory) under positive soundscape conditions, while the indoor data likely contributed contrasting or complementary responses that helped separate this pattern more clearly once pooled. Confirming this distinction would require a larger indoor sample, or a direct test of Indoor/Outdoor context as a variable within the same model.



## 6. Acknowledgements

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