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FIELD STUDY ON THE RESTORATIVE POTENTIAL OF SMALL GREEN AND BLUE SPACES IN DENSELY POPULATED AREAS

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ABSTRACT

The European Noise Directive mandates the identification and preservation of urban recreational spaces to protect them from additional noise and enhance their health-promoting potential. In Berlin, three categories of such spaces have been established, guided by criteria such as sound pressure level thresholds and the size of green spaces. The recently introduced third category, *urban quiet and recreational spaces* was created on the basis of participatory processes and lacks in objective assessment parameters. To account for that, we examined the perceived quality of four small green/blue areas ($< 30\ ha$) that could serve as recreational spaces and proposes potential criteria for their evaluation. Using on-site surveys derived from the Soundscape standard [1] and the Perceived Restorative Scale and its auditory pendant, 121 users were asked about their perceived level of restoration and the factors influencing it. The findings reveal that small urban locations were generally perceived as restorative, even though none were explicitly rated as quiet, suggesting that not primarily acoustic aspects may enhance their recreational value. While soundscape pleasantness strongly correlated with perceived restoration (PRSS), a varied and engaging sound environment seemed more influential than mere quietness, and elements like safety, cleanliness, accessibility, and activity options significantly influenced the locations' restorative potential. The findings highlight the importance of designing urban spaces that support diverse uses and sensory experiences.

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1. INTRODUCTION

Urban acoustic environments are inherently heterogeneous, exerting both positive and negative influences on city dwellers. Excessive noise exposure is well-documented as a contributor to stress and adverse health effects. However, less is known about the restorative potential of certain soundscapes, which are defined as "the acoustic environment as perceived by individuals and society" [2]. For example, quiet soundscapes have been shown to mitigate noise-induced annoyance, reduce stress, and enhance overall well-being [3], [4]. Recognizing the importance of such spaces, the European Union has mandated the identification and protection of quiet areas under the Environmental Noise Directive (END), accompanied by guidelines and recommendations for their designation [5]. Although there is government commitment, inconsistencies become visible during execution because a standardized framework for implementing these principles remains absent. This may be due to the lack of a clear and universally accepted definition of what qualifies an urban space as restorative. In current regulatory practice, municipalities typically define quiet/restorative areas using discrete categorical criteria, often based on factors such as green space size, specific land-use classifications, and predefined noise level thresholds [6]. In Berlin, a three-tiered approach is employed: (1) Quiet Areas, which must exceed 100 hectares and maintain noise levels below L_{den} = 55 dB(A); (2) Inner-City Green and

Restoration Areas, which require a minimum of 30 hectares and exhibit relative sound pressure level variations (a minimum 6 dB difference between the lowest and highest SPL values); and (3) "Städtische Ruhe- und Erholungsräume" (urban quiet and recreational spaces), which lack strict criteria so far. The third category will be introduced soon (2024) and was created on the basis of a participation process in which local experts could mark their preferred recreational/quiet areas [7]. The results suggest that neither minimum size nor noise levels alone adequately capture the restorative potential of an urban space. That is the reason why this study aims to evaluate whether small urban spaces, particularly those potentially classified under category 3, possess recreational qualities, both in general and in relation to their acoustic environment. We seek to uncover the underlying mechanisms that contribute to their perception as restorative by examining relevant contextual factors. Specifically, the study explores potential correlations between perceived restoration and a range of acoustic/non-acoustic factors.

2. METHODS

To approach the research questions, we carried out a field study with a between subject design. Data was collected at four distinct small urban sites that slightly varied in size and landscape typology (Table 1). We have deliberately chosen blue spaces, narrow river paths, as this particular setting is not listed under any category, but observed to be frequently used by the dwellers. To assess experiences and the acoustic properties of each location, a combination of on-site questionnaires and acoustic measurements was used. The questionnaire survey included several established instruments. Core of the questionnaire were the questions that asked for the Perceived Restorativeness Scale (PRS) [8], the Perceived Restorativeness Soundscape Scale (PRSS) [9] and the felt relaxation. The PRS is a well-established psychometric tool based on Attention Restoration Theory [10] that evaluates the restorative potential of physical environments through key dimensions such as Being Away, Fascination, Extent, and Compatibility; each dimension consists of a certain number of items. The PRSS extends this framework to the auditory domain, assessing how soundscapes contribute to perceived restoration. Given the strong construct validity of both scales, they provide robust assessment criteria. To evaluate the overall restorativeness of the study sites we looked at the average agreement of all four dimensions.

We added to the questionnaire, rating scale questions from ISO 12913-2 [1] for soundscape assessment (dominant sound sources, annoyance, perceived affective qualities (PAQ) and overall sound quality), to find out about the perceived acoustic qualities of the respective sites. Additionally, environmental variables such as view, accessibility, cleanliness, safety, and more were asked along with open-ended questions to capture qualitative insights (suggestions for improvements, reasons for feeling of restoration and the current activity). We added them to our questionnaire to understand underlining mechanism of the perceived restorativeness. To get a broader understanding of the investigated environment, acoustic measurements were made using a calibrated sound pressure level meter (NTI Acoustilyzer AL1 with MiniSPL, type II) and a calibrated binaural system (HEAD acoustics, SQuadriga I), which ensured measurements close to human hearing. These measurements were taken on spatial grids with minimum 17 measurement points at each study site at different times of the day. We did this to accurately map the acoustic environment and capture variations in sound pressure levels and auditory characteristics. Participants were randomly recruited on site by directly asking for collaboration to fill in a questionnaire that was accessible directly with the smartphone. Three students were assigned to lead the experiment. The sample finally consisted of 121 people (65 female, 2 non-binary), with approximately 30 individuals surveyed per site and it was observed that people sitting had a greater willingness to collaborate.

Data analysis incorporated both descriptive and inferential statistics. We process our findings using scatter plots, swarm-boxplots that include interquartile ranges, insights about the samples distribution, and central tendencies. These methods were used to visualize trends and variability of the perceived quantities. The results of the open-ended questions were analyzed by transforming them into wordclouds in which repeated mentions were visually highlighted. To explore bivariate relationships between variables, correlation analyzes using Pearson's r were performed and two-sided hypotheses were tested using p-values.

Figure 1. Most frequent activities, the size of the each word indicates its relative frequency

3. RESULTS

3.1 Predominant Activities

Participants were asked to describe their reasons for visiting the selected areas and the activities they preferred to engage there. The responses formed a diverse range of motivations and behaviors, visualized in the wordcloud (Fig. 1). The activities mentioned most frequently were related to physical activity. A considerable proportion of respondents visited these areas primarily for walking, followed by activities such as walking their dog, doing sports such as table tennis, running, and cycling. The second most common category of activities involved stationary or seated behavior, including sunbathing, having lunch, resting, contemplation, and reading. Social interactions also emerged as a key factor in site selection. Many participants indicated that they prefer to meet friends in these locations, while others mentioned dating or spending time on the playgrounds with their kids. It should be noted that the wordcloud may present a slightly skewed representation, as participants were allowed to provide multiple responses, potentially amplifying certain activities over others.

3.2 Restoration

To assess the restorative qualities of the investigated sites, we employed established psychometric approaches, including PRS, PRSS, and relaxation measures, which were all self reported on 5-point agreement/Likert scales. The PRS was adapted to include a single question per dimension, allowing us to evaluate the average agreement of the participants across all four dimensions (Fig. 2). The results indicate that all sites received generally high scores for perceived restoration, with slightly lower ratings observed at the smallest riverside location (UK). Although the overall score ranges were comparable across the four sites, greater variability in responses was observed in the designated green space (FR), suggesting a higher degree of individual differences in perceived restorativeness at this location.

Self-reported relaxation scores (Fig. 3) showed a consistent pattern across most sites with equal values for all four. Participants at UH, LI, and FR reported similarly high levels of relaxation, indicating a strong agreement on the restorative potential of these locations. The first site (UK), though, received scores that were more scattered.

The evaluation of the soundscape restoration qualities (Fig. 4) revealed generally moderate to good ratings, though they were lower compared to the PRS scores. No clear differences between the investigated sites emerged, with all locations exhibiting similar restorative potential. However, a slight preference for LI was observed, as it received the highest ratings, while UK was rated as having the

Table 1. For each area of investigation we specified the area size in hectares and the landscape typology including the predominant color. We supported the site-description by acoustic indices coming from ISO 12913-2 [1] (A-rated sound pressure level (slow/1s integration), 95th percentile Loudness (ISO 532-1), Sharpness (DIN 45634) and Roughness (ECMA-418-2)), psychoacoustic parameters were calculated for each channel separately, the higher value was selected.

Name	Size	Typology	L(A) eq	N5	S	R
Ufer Kaiserin-Augusta Allee (UK)	0.5 ha 500 m path	Blue area (river)	57.1	19.4	1.44	0.13
Ufer Helmholtzstraße (UH)	1 ha 900 m path	Blue area (river)	54.9	11.1	1.3	0.11
Lietzenseepark (LI)	10 ha	Green & blue area (lake)	56.7	12.8	1.49	0.12
Fritz-Schloß-Park (FR)	12 ha	Green area	54.1	7.28	1.35	0.11

lowest soundscape restoration quality.

3.3 Auditory Perception

All participants reported at least some level of annoyance at each of the four sites. However, the highest inter-quartile range was observed at UK, indicating greater variability in responses. Additionally, the higher arithmetic mean at this location suggests that participants experienced the most noise-related annoyance there, with some individuals reporting that they felt completely annoyed. UH and LI received the same values with low perceived noise annoyance. However, location FR received higher annoyance ratings even more than UK, looking at the average value. To gain deeper insights into the perceived acoustic qualities at each site, we analyzed responses to the ISO 12913-2 Likert-scale questions. The results were visualized using scatter density plots within the circumplex space, where values were scaled from 0 to 1, providing a relative measure of soundscape perception (Fig. 6). Overall, all four locations exhibited similar patterns: the majority of scores were slightly positioned in the upper-right quadrant, indicating that the soundscapes were perceived as vibrant which means pleasant, more eventful and less calm. However, UK deviated slightly from this trend. At this site, the soundscape was rated as more unpleasant, and the distribution of responses appeared more heterogeneous, suggesting a greater variability in perception among participants.

3.4 Correlation Analysis

A correlation analysis was conducted across all sites (N = 121) to investigate the underlying mechanisms influencing restoration ratings. The primary focus was on the relationship between the Perceived Restorative Soundscape Scale (PRSS), the non-acoustic related PRS and perceived acoustic dimensions. Looking at Fig. 7 the strongest positive correlation was observed between pleasantness ratings and PRSS, with highly significant p-values. The most notable negative correlation was between annoyance and PRSS, also showing high statistical significance. A significant positive correlation was found between PRSS and calm, while an inverse relationship was observed between PRSS and chaotic. No correlation was identified between eventfulness and PRSS. Regarding the Perceived Acoustic Qualities (PAQs), annoyance and pleasantness had the highest negative correlation, while pleasantness and calm showed the strongest positive correlation.

The correlation matrix (Fig. 8) revealed predom-

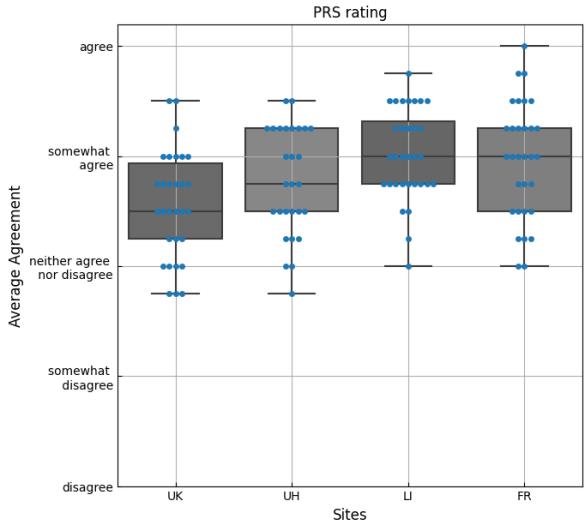

Figure 2. PRS score, mean values of agreement of all dimensions for each subject, stratified by survey location, we added the rating of each participant to the plot

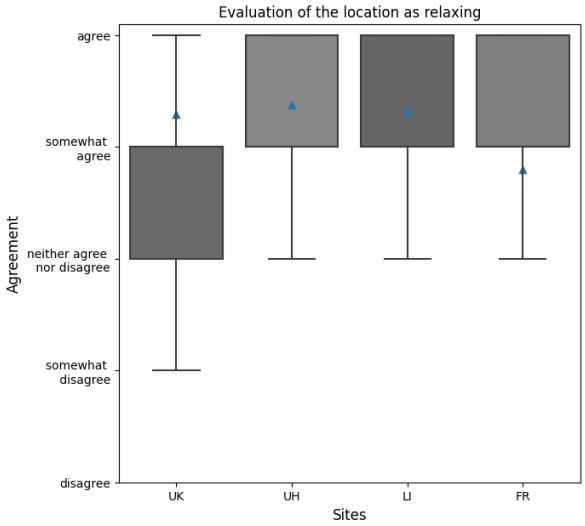

Figure 3. Agreement on the question wether people were capable to relax at the respective site, the blue triangles mark the arithmetic average

inantly positive relationships between PRSS, PRS, and various non-acoustic factors, with only a few non-significant negative correlations.

It should first be emphasized that a highly significant correlation was found between PRSS and PRS. Correlations between non-acoustic factors showed strong relationships, including nature and view, nature and accessibility, accessibility and proximity to home, cleanliness and maintenance, nature and maintenance, possible uses and maintenance, number of people and safety, as well as conflicts of use and safety. Looking at PRSS and non-acoustic factors, correlation values did not exceed 0.5, suggesting a lower influence of non-acoustic factors on PRSS. The most significant correlation was observed between PRSS and nature. The second strongest correlation was with maintenance, which was also linked to cleanliness. Accessibility was also correlated with PRSS. The correlation patterns between PRS and non-acoustic factors were similar to those of PRSS but with some differences. Nature had the highest correlation with PRS, followed by maintenance and possible uses. Safety was the third most significant factor associated with PRS, and accessibility also played a role in PRS ratings.

4. DISCUSSION

This study aimed to assess whether small urban locations possess recreational qualities, both in general and in relation to their perceived acoustic environment. The findings provide valuable insights into respondents' perceptions at the surveyed locations. Across all four locations, participants generally perceived restoration, as indicated by the positive average agreement in both the PRS and its soundscape-adapted counterpart (PRSS) (see fig. 2 and fig. 4). This is further supported by responses to an open-ended question on activities, where many participants mentioned visiting these locations to rest or relax. Interestingly, a comparison between PRSS and PRS revealed that the noise-independent perception was rated slightly higher across all sites. This suggests that visual conditions or the interplay of multiple sensory impressions may enhance the restora-

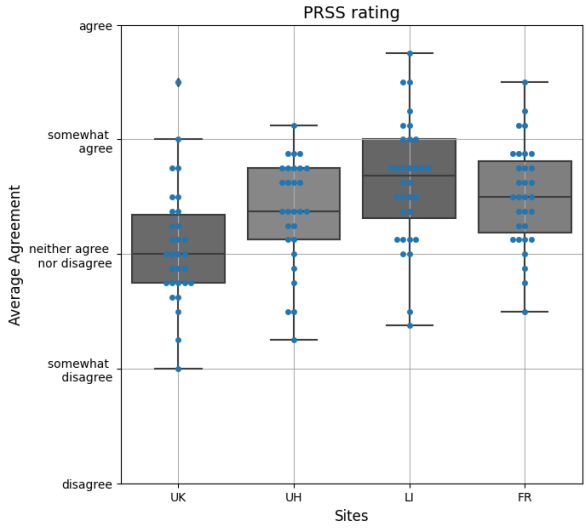

Figure 4. PRSS score, mean values of all dimensions for each subject, stratified by survey location, the blue dots mark each praticipants' average agreement

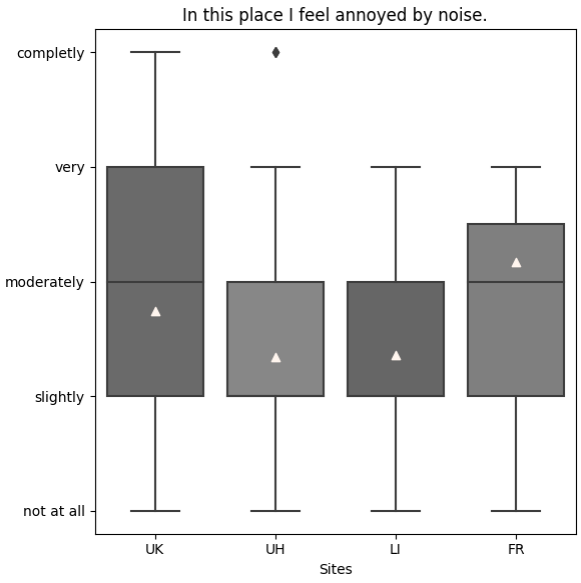

Figure 5. Noise annoyance ratings, the white triangles mark the arithmetic average, while the black horizontal line in the center of each box represent the median value, in the case of UH and LI it's the lower line of the box

tive potential of these small urban locations. Furthermore, when participants were asked directly whether they could relax at a location, their agreement rating was even stronger than in PRS and PRSS scores. This indicates that while both scales capture perceived relaxation, PRSS is more closely linked to acoustic factors, which were found to be suboptimal at the selected areas. A surprising result was the high level of noise annoyance reported at the FR location, despite its low measured loudness values. That might be because of the presents of specific sonic events—potentially those with strong informational content. Analysis of the PAQ values didn't reveal any major trends, but overall, each locations was perceived as both pleasant and eventful, despite their relatively high loudness values. Notably, responses at the UK location were particularly polarized, which may be attributed to the presents of road traffic noise and situational influences. None of the locations were explicitly rated as "quiet," yet they were still perceived as recreational, as indicated by direct responses and PRS scores. This suggests that auditory perception may play a less dominant role in the overall restorative quality of a place than initially assumed. If we consider the acoustic qualities in relation to the recreational quality, we observe that the correlation between PRSS and acoustic pleasantness was strong, confirming that acoustic pleasantness is a key factor in the perception of a location as restorative. However, vibrancy and calmness contributed less to PRSS ratings, implying that a varied soundscape, rather than a strictly quiet one, may play a decisive role in perceived restoration. An unexpected finding was the relatively weak negative correlation between eventful and uneventful soundscapes. These categories should theoretically function as opposites, but their weak correlation raises questions about the validity of the measurement construct used in this study. Furthermore the correlation between PRS scores and the availability of possible usage options is particularly interesting. Respondents tended to

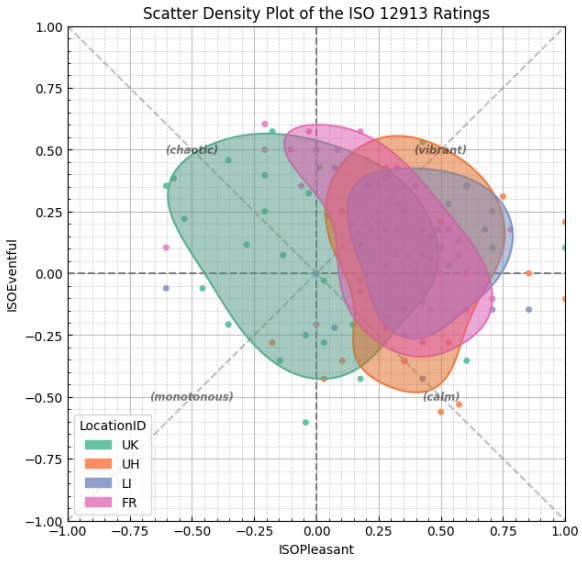

Figure 6. Measured perceived affective qualities, transformed into a two dimensional space, stratified by location and represented with the 50th percentile contour

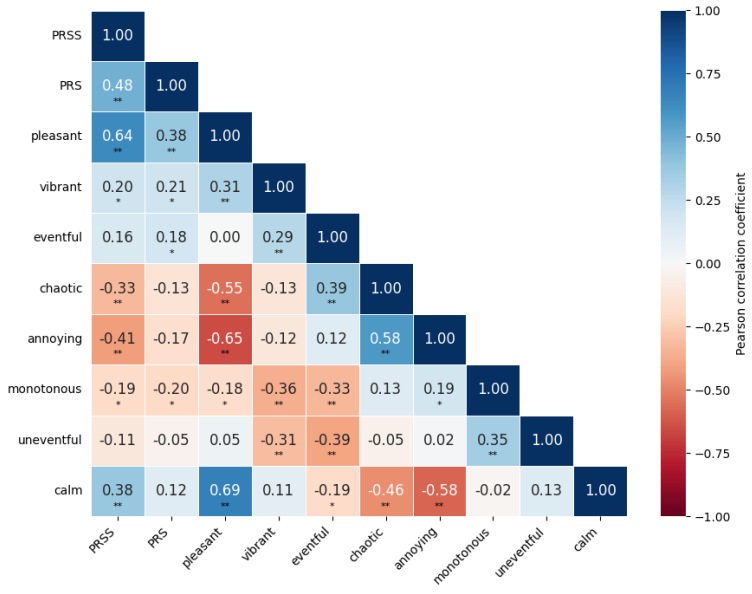

Figure 7. PAQs correlated with PRSS, with significance marking asterisks: p-values ** < 0.01, * < 0.05, and non

find places more restorative when they offered a variety of uses, suggesting that individuals have a multifaceted set of requirements for a location to be perceived as restorative. This is further supported by the wordcloud analysis, which highlights the range of activities mentioned by participants. To accommodate a broad spectrum of visitors, urban spaces should ideally provide diverse activity options. Safety and cleanliness emerged as expected criteria, with strong correlations to recreational value, further emphasizing their importance for urban restorative spaces. Accessibility also played a crucial role in the perceived recreational value of a location. As highlighted in the Noise Action Plan of Berlins' recent noise action plan [7], ease of access can be a decisive factor in whether an area is actually used for recreation. Despite these insights, certain limitations must be acknowledged. The study design allows for the identification of trends but does not support definitive causal conclusions. The potential presence of intercorrelations suggests that future research should involve testing individual hypotheses to refine these findings further. Nonetheless, the observed internal consistency improves our understanding of the mechanisms underlying restorative qualities in urban environments.

5. SUMMARY

This study examines smaller green and blue urban areas that do not officially meet the criteria to be classified as restorative spaces. Despite this, our investigation revealed that people actively seek out these places for restoration. We found that a variety of activities were performed in these areas, primarily related to physical exercise, suggesting that the availability of space for diverse activities may influence their perceived restorative qualities. Interestingly, reduced loudness or noise annoyance weren't the primary contributors to perceived relaxation. Instead, a wide range of non-acoustic factors played a significant role in shaping the restorative experience. Our findings indicate that restoration is a mul-

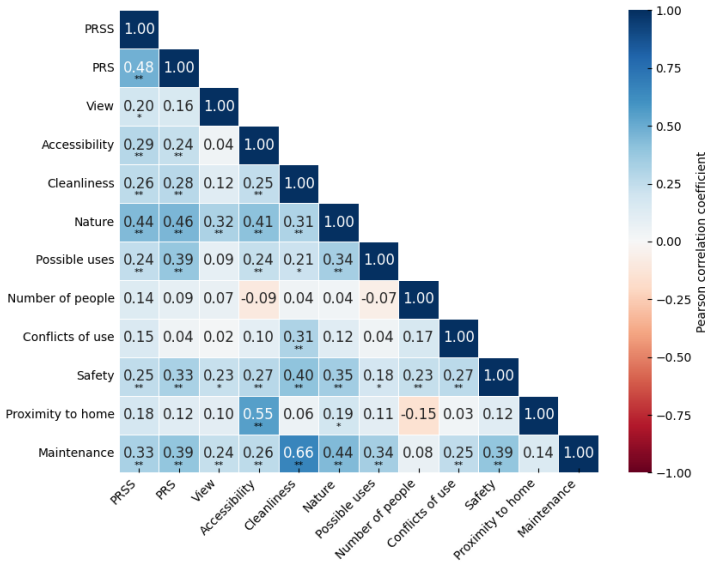

Figure 8. Some correlations, with significance marking asterisks: **, *, and non

tifaceted construct, strongly moderated by contextual factors. Due to the exploratory nature of our study, we cannot make definitive statements about the individual functions of restorativeness. However, we identified trends that should be further investigated in more controlled environments to deepen our understanding of how urban spaces contribute to well-being.

6. ACKNOWLEDGMENTS

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