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Real-Time Physiological–Psychological Responses in Diverse Community Scenes During Dynamic Walking Experience

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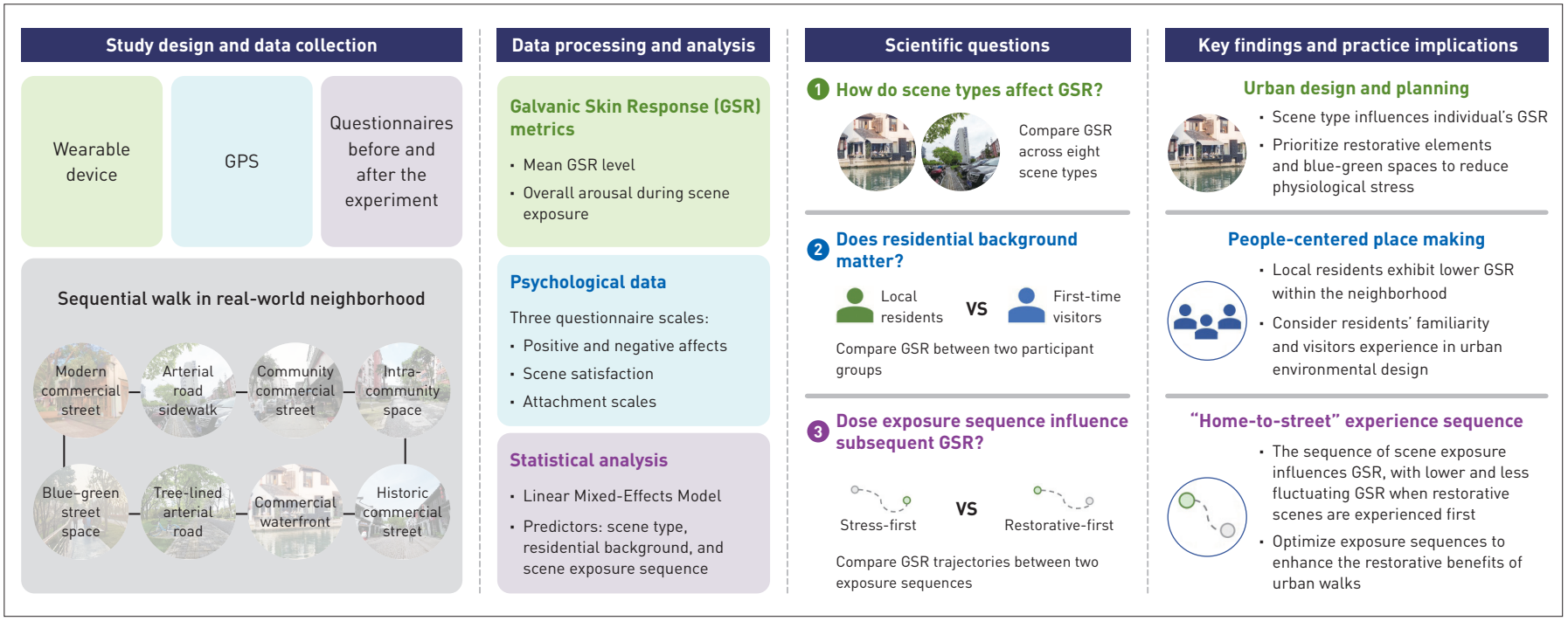
GRAPHICAL ABSTRACT



ABSTRACT

Neighborhood spaces play a vital role in residents' physical and mental well-being. However, prior empirical research has largely been confined to a binary "urban–nature" paradigm, with limited attention to the spatiotemporal dynamics of individuals' continuous scene experiences in real-world settings. This study focused on an aging residential community and its surrounding commercial facilities in Wuxi, China, employing wearable physiological sensors to continuously monitor the physiological responses of 48 participants during field walking. We systematically examined the effects of eight everyday scene types on galvanic skin response (GSR) and its dynamic variation, as an indicator of physiological arousal, among local residents and first-time visitors.

Research results showed that: 1) Scene type had a highly significant effect on GSR in both local residents and first-time visitors, with the former exhibiting greater sensitivity to scene type, sound pressure level, and scene exposure orientation. Post hoc tests indicated that blue–green spaces were the most restorative scene type. 2) Local residents exhibited lower and more stable

GSR levels in community scenes compared with other scene types, whereas first-time visitors showed significantly higher GSR in community scenes than that in commercial and street scenes; however, the length of residence did not significantly moderate individual GSR levels. 3) The sequence of exposure to different scene types significantly moderated physiological arousal responses—participants who were exposed to restorative scenes earlier in the walking sequence exhibited lower and more stable GSR levels, and the effect that was particularly pronounced among local residents, suggesting that early exposure to restorative scenes helps establish a lower physiological arousal baseline.

These findings offer practical implications for future community regeneration: community space can act as a stress buffer in residents' daily lives, with greater attention given to the provision of comfort-enhancing amenities in commercial spaces. Optimizing the spatial sequencing may further support daily environmental experiences that promote physiological regulation and psychological stability.

KEYWORDS

Restorativeness; Community Regeneration; Well-Being; Wearable Physiological Sensors; Place Attachment; Positive and Negative Affect

HIGHLIGHTS

- Wearable physiological sensors captured arousal across eight real-world urban scenes
- Scene type significantly shaped physiological arousal in residents and visitors
- Community scenes elicited lower GSR among local residents but relatively higher GSR among first-time visitors
- Exposure order modulated GSR baseline; restorative scenes first lowered arousal

RESEARCH FUND

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1 Background

1.1 Scene Types and Restorative Benefits in Urban Communities

In existing research, studies on the health benefits of urban community environments have predominantly adhered to a nature–built binary paradigm[1]. This perspective emphasizes the restorative value of natural landscapes (e.g., parks, forests) while simultaneously framing the crowded and disordered built environment as a primary source of stress[2–3]. The theoretical emphasis of classical Stress Recovery Theory[4] and Attention Restoration Theory[5] on natural environments has produced a notable paradigmatic bias in this field of inquiry: studies routinely contrast positive natural environments (i.e., blue–green spaces characterized by tranquility and openness, such as forest parks and waterfront promenades) with negative urban built environments (e.g., arterial roads)[6–7], and these two categories of space are frequently employed as reference conditions against which to examine individuals' physiological and psychological arousal responses.

Yet cities contain a rich diversity of everyday scene types (such as vibrant commercial streets[6] and tranquil cafés[8]) and a range of amenity facilities[9]①. A well-designed commercial street may generate a form of positive health benefit distinct from "relaxation" by offering novel experiences, facilitating social interaction, and cultivating a sense of vitality. However, existing research has tended to examine such positive scenes and natural environments within separate paradigmatic frameworks, and direct cross-comparisons among multiple types of positive scene within a single experimental design remain scarce[10]. It is therefore necessary to situate multiple community space types, including water bodies, green spaces, commercial areas, and intra-community spaces within a unified experimental framework for comparative studies, rather than consistently benchmarking them against a single "negative scene" as the control condition. This study accordingly selects multiple scenes as the experimental independent variable to investigate the effects of different urban scene types on physiological arousal.

1.2 Environmental Familiarity and Physiological Arousal

An individual's physiological and psychological responses to a particular daily space are not determined solely by the physical characteristics of that space; they are also closely related to the individual's long-term experience of residing in and using that environment[11]. Repeated environmental exposure and habitual

① Amenity refers to facilities of various types that provide residents with everyday convenience and enjoyable experiences.

use reinforce an individual's sense of safety[12] and behavioral expectations[13] within a given space, which in turn shapes his/her emotional experience and physiological response patterns[14]. Existing research indicates that long-term residential experience leads to more strongly expressed positive affect during everyday environmental exposure[15], and that the distress experienced when one anticipates leaving a familiar place, or when that environment undergoes negative change is correspondingly more acute[16].

Compared with local residents, first-time visitors lack the prior spatial knowledge and contextual familiarity associated with a particular neighborhood and its surroundings. This study therefore recruited two groups of participants—local residents and first-time visitors—to examine how environmental familiarity and long-term exposure experience affect the physiological arousal responses of individuals with different residential backgrounds when confronting identical community scenes.

1.3 Temporal Dimension of Environmental Exposure

An individual's psychological experience within a real community environment is not isolated; rather, it is embedded within a spatiotemporal trajectory. In responding to basic survival needs, individuals shape regular and cyclical patterns of spatiotemporal behaviors[17]. Daily activities possess characteristics of continuity and sequentiality, meaning that the effects of an activity context persist over time and may manifest as lagged effects[18]. Positive affect perceived in the environment can help individuals reduce reactivity to negative events and more readily notice, generate, and sustain positive emotional states[19]. Maintaining a positive orientation during periods of stress can, in turn, cultivate psychological resilience, enabling effective adaptation and swift recovery[20].

Taken together, this study hypothesizes that scene exposure sequence may produce a lagged influence on changes in an individual's physiological arousal. If a participant is first exposed to a stressful scene, their elevated level of physiological arousal may carry over into subsequent scene experiences whereby residual physiological state from the preceding condition affects measurement under the following condition constituting what is termed a carryover effect in experimental design.

The research addresses three key questions arising from real-world urban scene experience: 1) Whether different scene types elicit differential physiological arousal responses in order to identify the relationship between urban scene attributes and galvanic skin response? 2) Whether individuals with different residential backgrounds differ in their physiological feedback during scene experience, and whether long-term environmental experience and site familiarity influence individuals' responses to scene stimuli? And 3) how does the scene exposure sequence influence subsequent physiological states, and whether prior exposure to stressful or restorative scenes alters Galvanic Skin Response (GSR) level and fluctuation characteristics in subsequent experiences?

These questions operate at the levels of scene attributes, individual experience, and dynamic exposure process, respectively, and together constitute the analytical framework through which this study explains differential physiological arousal responses across real-world urban scenes.

2 Methods

2.1 Instrumentation

Two instruments were used in this study. First, an Empatica E4 medical-grade wearable wristband was used to collect physiological data—this device has been widely applied in environmental psychology research[21]. GSR was used to represent changes in sympathetic nervous arousal. Heightened physiological arousal corresponds to increased alertness and stress, whereas decreases in sympathetic nervous activity are reflected in declining GSR when the environment is perceived as safe and restorative. The E4 recorded at a sampling rate of 4 Hz, enabling precise capture of short-term physiological fluctuations. During the experiment, the wristband was worn on the non-dominant wrist of each participant. Second, GPS trajectory data were simultaneously recorded via the Two-Step application at a frequency of 1 Hz; location access was granted through the application, with a positioning accuracy of ±5 m. All sensors were calibrated by research staff prior to attachment.

2.2 Study Design

2.2.1 Experiment Site Selection

This study selected Nanchangjie historic commercial area in Wuxi and the adjacent Tangnan Xincun Neighborhood as the experimental site. Nanchangjie is a historic cultural and commercial area that integrates historic architecture, waterfront landscapes, and commercial spaces; Tangnan Xincun Neighborhood, established in the 1950s, has preserved the spatial fabric and the daily features of older residential neighborhoods in the city. The two areas are in close proximity, yet differ markedly in historical development, spatial morphology, functional composition, environmental maintenance standards, and patterns of user activity, which provide an appropriate experimental setting for comparing physiological arousal responses across varied urban scene types.

The experimental route was determined by considerations of representativeness and controllability. First, the route should connect, within a compact walking distance, a range of representative daily urban scene types such as historic commercial spaces and older residential spaces. Second, each segment should be consecutively linked and of comparable length, thereby minimizing interference from walking time and measurement duration differences arising during scene transitions. Finally, eight consecutive route segments were selected, comprising 1) modern commercial street; 2) arterial road sidewalk; 3) community commercial street; 4) intra-community space; 5) blue–green street space; 6) tree-lined arterial road; 7) commercial waterfront; and 8) historic commercial street (Fig. 1).

The experiment was conducted in two walking directions. The clockwise route proceeded from stressful scenes to restorative scenes (sequence: 1–2–3–4–5–6–7–8–1), while the counterclockwise route proceeded from restorative scenes to stressful scenes (sequence: 1–8–7–6–5–4–3–2–1).

2.2.2 Experimental Procedure

During the experiment, participants wore both sensor types (wristband and GPS tracker) and were free to wander in the experimental site. Every scene walking was followed by a 3-minute rest, with the full experiment taking approximately one hour (Fig. 2).

The experiment was conducted from April to May 2024. Participants were recruited via social media platforms and local community committees and service centers. Eligibility criteria were as follows: 1) local residents must have resided in the area for more than one year, and first-time visitors must never have previously visited the experimental site; 2) participants must have no history of psychotropic medication use; 3) participants must have passed the Perceived Stress Scale (PSS) test and been found to be at a normal or above-normal stress level; and 4) participants must have abstained from caffeinated beverages for six hours prior to the experiment. A total of 48 participants were recruited (23 males, 25 females), comprising 18 local residents and 30 first-time visitors (Table 1).

Fig. 1 Study area and experimental route.



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Fig. 2 Experimental procedure, instrumentation, protocols, and participant statistics.

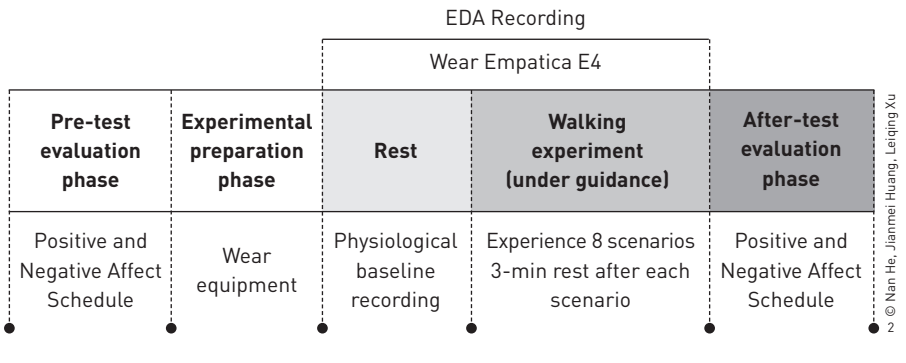

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Table 1: Participant demographic characteristics

Variable	Category	Number of participants
Gender	Male	23
	Female	25
Age	18–35 years	30
	35–45 years	15
	Over 45 years	3
Group	Local resident	18
	First-time visitor	30
Length of residence	Short-term (≤ 2 years)	7
	Medium-term (3–9 years)	7
	Long-term (≥ 10 years)	4

Prior to the experiment, each participant read and signed a research information sheet and informed consent form. A five-minute sensor orientation session was provided to each participant. The experiment was conducted in two batches: the first-time visitor group completed the full experimental protocol first, followed by the local resident group one week later. During each experimental session, two same-group participants took part simultaneously (either both first-time visitors or both local residents), who walked in opposite directions (Fig. 2). Before and after the experiment, participants completed the Positive and Negative Affect Schedule (PANAS) to measure the emotional effects of the walking experiment.

This research was approved by the Science and Technology Ethics Review Committee of Tongji University and complied with the relevant regulations of the Research Administration Division of Tongji University.

2.3 Data Analysis

2.3.1 Physiological Data Processing and Statistical Analysis

The physiological data collected in this study underwent signal quality screening, motion artifact removal, spatiotemporal data alignment, and scene boundary segmentation. The GSR data exhibited typical repeated-measures characteristics, with each participant measured across eight distinct scenes while individual physiological baselines varied. A Linear Mixed-Effects Model (LMM) was therefore employed for analysis. Compared with approaches such as ordinary linear regression, LMM can estimate population-level regularities while accommodating individual-level variation in baseline physiological levels. In other words, it can simultaneously address the question of which factors systematically influence GSR and acknowledge that participants differ in their underlying physiology.

Tukey's post hoc pairwise comparison was also applied to verify whether significant GSR differences existed between specific pairs of scene types. To further examine whether length of residence modulates individual GSR arousal patterns, regression analyses were conducted between local residents' length of residence with both their mean GSR values and within-scene GSR change rates. The analysis of the association between length of residence and mean GSR tested whether long-term residential experience affects overall physiological arousal across scenes, while the other analysis explored whether the length of residence moderates the trajectory and adaptive characteristics of individual's arousal responses during scene exposure.

2.3.2 Psychological Data Processing and Statistical Analysis

During the recruitment phase, the PSS[22] was used to screen participants' baseline mental health status via self-report, ensuring that all participants were in an adequate state of well-being at the time of participation. The PANAS[23] was administered before and after the experiment to assess participants' affective state and capture emotional changes across the scene experience. Both the PSS and PANAS used a 5-point Likert scale (1 = not at all; 5 = extremely). In addition, following the experiment, a satisfaction scale was administered to collect participants' evaluations of each scene (1 = very dissatisfied; 5 = very satisfied). For the affective data, paired-sample *t*-tests were conducted to compare the pre- and post-experiment PANAS scores, thereby testing the psychological effects of different scene experiences. Pearson correlation analysis was also used to examine the association between affective change and GSR.

3 Results

3.1 Physiological Response Findings

3.1.1 Physiological Arousal Across Scene Types

LMM results (Table 2) indicate that scene type exerted a highly significant effect on participants' GSR, with the effect being slightly stronger for local residents ($\beta = 0.029$, $p < 0.001$) than for first-time visitors ($\beta = 0.024$, $p < 0.001$). As the experiment progressed, all participants exhibited a fatigue effect alongside a slight increase in physiological arousal in the later stages. Route direction also influenced participants' GSR. The "priming effect" of prior exposure to restorative scenes in the exposure sequence carried physiological regulatory significance, and this effect was most pronounced in the local resident samples. First-time visitors likewise showed a significant fatigue effect, though its magnitude was comparatively smaller. Ambient temperature on the day of the experiment had no significant effect on participants' GSR. Sound level (dB) significantly influenced participants' GSR—higher sound levels were associated with higher GSR—and local residents' physiological arousal was more sensitive to ambient sound level than that of first-time visitors.

3.1.2 Physiological Arousal in Local Residents Versus First-Time Visitors

Based on the LMM results, scene type exerted a significant effect on GSR in both participant groups; however, LMM can only establish that scene type has an overall effect and cannot further identify the specific differences between individual pairs of scenes. To clarify the differences among scene types and to compare whether the response patterns of local residents and first-time visitors were

Table 2: Linear mixed-effects model results for GSR responses

Variable	β		Interpretation
	Local resident	First-time visitor	
Scene type	0.029 ($p < 0.001$)	0.024 ($p < 0.001$)	Scene type significantly affects GSR
Experiment progress	0.130 ($p < 0.001$)	0.085 ($p < 0.001$)	GSR increases over the course of the experiment, indicating a fatigue effect
Route direction	−3.150 ($p < 0.001$)	−0.047 ($p < 0.001$)	Counterclockwise route associated with lower GSR; local resident's GSR more responsive to route direction
Ambient temperature (°C)	−0.110 ($p = 0.385$)	0.005 ($p = 0.640$)	Temperature does not significantly affect GSR
Sound level (dB)	0.093 ($p < 0.001$)	0.054 ($p < 0.001$)	Sound intensity significantly affects GSR: higher dB corresponds to higher GSR
Individual variance (random effect)	1.038	0	Participants differ in physiological baseline; inter-individual variance is greater among local residents

consistent, Tukey's method was applied separately to each group for pairwise scene comparisons. Results revealed that both local residents and first-time visitors achieved the lowest GSR in the blue–green street space (Tables 3, 4), with smaller within-group standard deviations.

For the local resident samples, the intra-community space returned a mean GSR of 8.51—significantly lower than the arterial road sidewalk, the community commercial street, and all commercial scene types, and exceeded only by the blue–green street space. This indicates that local residents' overall physiological

Table 3: Mean GSR values by scene type and Tukey's post hoc pairwise comparison results among the local resident samples

Scene type	Mean GSR	Modern commercial	Arterial road sidewalk	Community commercial street	Intra-community space	Blue–green street space	Tree-lined arterial road	Commercial waterfront	Historic commercial street
Modern commercial street	10.85	—	0.920	0.005	< 0.001	1.000	1.000	0.049	< 0.001
Arterial road sidewalk	9.90		—	1.000	0.008	0.046	0.037	< 0.001	< 0.001
Community commercial street	9.66			—	0.024	1.000	0.986	< 0.001	< 0.001
Intra-community space	8.51				—	0.076	0.003	< 0.001	< 0.001
Blue–green street space	7.85					—	1.000	0.003	< 0.001
Tree-lined arterial road	8.79						—	0.017	< 0.001
Commercial waterfront	10.60							—	< 0.001
Historic commercial street	12.13								—

Table 4: Mean GSR values by scene type and Tukey's post hoc pairwise comparison results among the first-time visitor samples

Scene type	Mean GSR	Modern commercial	Arterial road sidewalk	Community commercial street	Intra-community space	Blue–green street space	Tree-lined arterial road	Commercial waterfront	Historic commercial street
Modern commercial street	4.97	—	1.000	< 0.001	< 0.001	1.000	0.127	0.118	0.038
Arterial road sidewalk	5.57		—	< 0.001	< 0.001	0.037	0.046	0.893	0.734
Community commercial street	6.55			—	0.029	< 0.001	0.806	0.015	0.005
Intra-community space	7.04				—	< 0.001	0.002	< 0.001	< 0.001
Blue–green street space	4.85					—	0.002	0.005	< 0.001
Tree-lined arterial road	5.28						—	1.000	1.000
Commercial waterfront	5.40							—	1.000
Historic commercial street	5.66								—

arousal was in a lower range within community environments, with the sense of security and emotional stability afforded by environmental familiarity reducing physiological load. In contrast, local residents exhibited significantly higher GSR in the historic commercial street and the commercial waterfront relative to all other scenes (Table 3).

In contrast, both the intra-community space and the community commercial street elicited higher GSR among first-time visitors (Table 4). The intra-community space yielded the highest mean GSR (*Mean* = 7.04), significantly exceeding all other scene types ($p < 0.05$), indicating that first-time visitors were in a heightened state of physiological alertness upon entering community environments. Conversely, first-time visitors displayed significantly lower GSR on the arterial road sidewalk compared with community scenes. The blue–green street space (*Mean* = 4.85) and the modern commercial street (*Mean* = 4.97) returned the lowest GSR, and first-time visitors' GSR in the blue–green street space was significantly lower than in all other scenes except the modern commercial street.

The study analyzed participants' mean within-scene GSR rate of change during each scene experience. Results showed that local residents' GSR declined continuously throughout the intra-community space as the experiment progressed, whereas first-time visitors' GSR increased within community scenes (Table 5).

Table 5: Mean within-scene GSR rate of change by participant group

Group	Scene type							
	Modern commercial	Arterial road sidewalk	Community commercial street	Intra-community space	Blue–green street space	Tree-lined arterial road	Commercial waterfront	Historic commercial street
Local residents	0.104	0.028	−0.004	−0.004	−0.011	0.029	−0.130	0.012
First-time visitors	0.014	0.040	0.027	0.038	−0.027	0.011	−0.116	0.017

Across all scene types, the commercial waterfront space elicited the greatest GSR decline, followed by the street-front blue-green space, both of which exhibited a pronounced trend of decreasing physiological arousal.

To further test whether length of residence influenced individual's physiological arousal responses, regression analyses were conducted between local residents' length of residence with both their mean GSR values and within-scene GSR change rates. To mitigate the potential influence of a small number of long-term residents on regression results, the length of residence was log-transformed. Results revealed no significant regression relationships between log-transformed length of residence and either physiological indicator. Although length of residence showed no significant linear association with GSR change rate. This suggests that, in the present study, sample group (local residents versus first-time visitors) exerted a significant effect on responses, whereas the length of residence as a continuous variable produced no additional linear effect. Environmental familiarity thus appears to operate more as a categorical effect—in other words, transitioning from "unfamiliar" to "familiar" is sufficient to produce a difference, rather than accumulating linearly with increasing length of residence as a dose–response relationship.

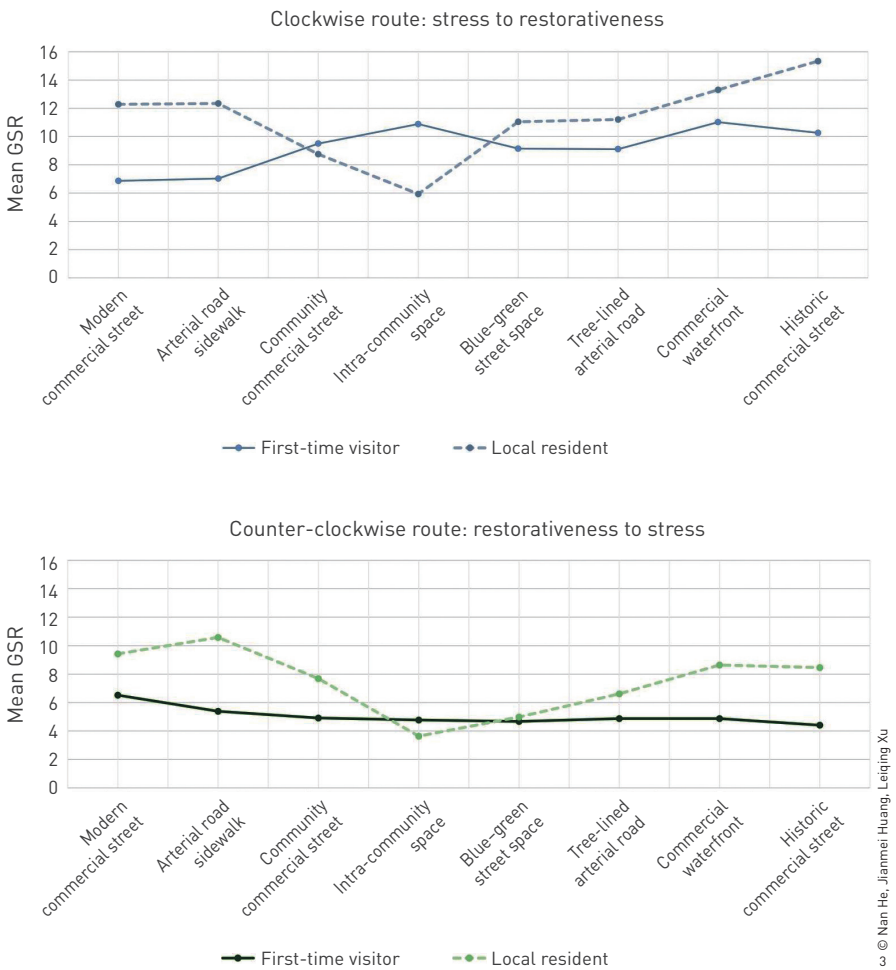

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Fig. 3 Mean GSR changes by scene exposure sequence and route direction.

3.1.3 Route Direction and Physiological Arousal

Table 6 presents GSR results by experimental route direction. Regardless of residential background, participants on the counterclockwise route (restorative scenes to stressful scenes) maintained lower mean GSR values and smaller standard deviations than those on the clockwise route. This indicates that prior exposure to restorative scenes effectively reduces physiological arousal and produces greater physiological stability.

As shown in Fig. 3, scene exposure sequence and participant group exerted a significant interactive effect on physiological arousal. Under the clockwise route, participants' mean GSR was consistently higher than that under the counterclockwise route, indicating that initial exposure to stressful environments prevented physiological arousal from fully recovering during subsequent restorative scenes, and reflecting a pronounced carryover effect. Under the counterclockwise route, participants' overall GSR was maintained at a lower level, suggesting that prior experience of restorative scenes provided a buffering effect against the physiological impact of subsequent stressful scenes.

Furthermore, local residents' physiological sensitivity to scene transitions was significantly greater than that of first-time visitors. Under both route conditions, local residents' mean GSR reached 12–15 in commercial scenes and on arterial road sidewalks, falling to 3.6–5.9 in community and natural scenes. Through prolonged everyday engagement with these spaces, they have developed experience-based physiological arousal patterns specific to familiar places, influenced by factors such as the particular attributes of each space and their history of use therein. Correspondingly, they

Table 6: GSR responses by route direction

GSR	Full sample		Clockwise		Counter-clockwise	
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***
Local residents (*N* = 18)	9.74	9.33	10.72	10.81	8.58	6.86
First-time visitors (*N* = 30)	5.84	4.75	7.02	6.07	4.95	2.32

may also be more sensitive to the meanings and associations carried by familiar environments, rather than merely their surface physical properties. In contrast, first-time visitors' GSR curves were comparatively flat, with smaller inter-scene differences (Fig. 3).

3.2 Affective and Satisfaction Findings

Cronbach's α coefficients for the positive affect and negative affect subscales were 0.88 and 0.87, respectively, both exceeding 0.80, confirming good internal consistency and reliability. Paired-sample *t*-test results showed no significant difference in positive affect scores before and after the experiment for first-time visitors; local residents' negative affect scores, however, decreased significantly (mean difference = 2.16, $p = 0.040$). The experimental results thus indicate that negative affect among local residents was significantly reduced.

Independent-samples *t*-test results showed that local residents reported higher overall scene satisfaction compared with first-time visitors, and this difference was of moderate effect size (Cohen's $d = 0.50$).

4 Discussion

4.1 Scene Type and Restorative Benefits

Controlling for the confounding effects of scene exposure sequence and participant fatigue, which are the factors often neglected in prior research, results demonstrate that community scene type exerts a significant effect on physiological arousal responses.

First, blue–green spaces significantly ameliorated GSR; the restorative mechanism of greenery on physiological arousal is corroborated by the contrast between the arterial road and the tree-lined arterial road scenes. Regardless of residential background, participants' GSR in the tree-lined arterial road scene was significantly lower than on the arterial road, where motorized traffic constituted the primary stressor. Existing literature documents the significant restorative effect of waterfront spaces[24]. The present study found that GSR change rate in the commercial waterfront was negative and of greater absolute magnitude (Table 5), indicating that this scene type has a certain arousal-reducing effect. Moreover, participants' mean GSR in blue–green spaces was the lowest, with a smaller standard deviation (Tables 3–5), indicating that such spaces not only lower overall physiological arousal but also stabilize physiological state and reduce inter-individual variability.

First-time visitors maintained a low and stable mean GSR in the modern commercial street. Although commercial spaces are generally regarded as high-stimulation, high-density urban environments, a well-designed and well-maintained commercial environment did not produce the anticipated physiological arousal in first-time visitors. The outdoor seating, shade canopies, and similar features present in modern commercial spaces provide the material conditions for resting and social interaction[25], thereby enhancing environmental affordance. Environmental affordance communicates behavioral cues that permit pedestrians to rest without requiring them to deliberate extensively about how to use the environment, and may thereby reduce psychological stress and enhance perceived safety.

4.2 The Significance of Community Scenes for Local Residents' Well-Being

Experimental results indicate that participants first exposed to restorative environments and subsequently exposed to stressful environments maintained lower mean GSR values and smaller standard deviations compared with participants exposed in the reverse order. LMM results confirm that scene exposure sequence significantly moderated participants' GSR, and that this effect was stronger for local residents.

For local residents, community scenes possess restorative benefits that warrant serious attention. The experimental site in this study comprised older urban residential neighborhoods whose community environments and community commercial environments were rated by residents as the least satisfying scenes. Despite this, Tukey post hoc comparisons revealed that local residents' GSR in community scenes was at a relatively low level. Specifically, the intra-community space exhibited GSR values significantly lower than all scene types except the blue–green street space, and a declining GSR trend was observed within the intra-community space, a pattern entirely opposite to that of first-time visitors. Local residents also reported more pronounced emotional responses within community environments, reflecting psychological states of safety, pleasure, and relaxation. The intra-community space is the primary setting for local residents' daily social interactions and physical activities. Given that prior exposure to restorative environments exerts a protective effect by establishing a lower physiological arousal baseline and enhancing physiological stability, high-quality community scenes can function as a "physiological stress buffer" in local residents' everyday lives, providing not only immediate physiological regulation but also contributing to the long-term construction of psychological resilience through sustained positive experience. These findings

offer important scientific grounds for health-oriented community planning, design, and regeneration.

4.3 Limitations and Future Directions

This study is subject to certain sample-related limitations. First, the number of valid participants was relatively limited, and there was a considerable imbalance in sample size between the local resident and first-time visitor groups. Although the LMM approach for repeated-measures data was employed, with individual-level random effects specified to partially control for between-subject baseline differences, this method cannot fully compensate for the statistical limitations arising from insufficient sample size and unequal group allocation. Future studies should replicate the present findings with larger samples and, where possible, optimize the balance of proportions across participant groups. Replication across multiple neighborhoods, multiple cities, and different community typologies would also enhance the robustness of statistical results and the generalizability of conclusions.

Second, while GSR reflects sympathetic nervous activity, it cannot distinguish between positive and negative arousal. Future research could integrate additional physiological indicators to strengthen explanatory power, and could combine neuroimaging techniques (e.g., fMRI, EEG) to investigate the neural mechanisms through which restorative pathways—such as place attachment and social interaction—affect individuals.

Finally, the one-hour experimental duration did not permit the capture of long-term exposure effects. Subsequent research could adopt longitudinal tracking designs to further validate the findings reported here.

5 Conclusions

Transcending the nature–built binary experimental paradigm that has characterized prior research, this study employs an *in situ* experimental approach to systematically examining the mechanisms by which different community scene types affect individual physiological arousal responses. Eight representative spatial types were selected for the experimental route, and wearable physiological sensors combined with GPS positioning technology were used to monitor participants' physiological responses throughout the full experimental process. The study was supplemented by psychological scales to produce a comprehensive physiological–psychological–spatial multidimensional dataset.

The results can be summarized as follows. First, scene type exerted a highly significant effect on participants' GSR, with the blue–green street space identified as the most restorative scene. For first-time visitors, the modern commercial street exhibited the second-highest restorative benefit. Both local residents and first-time visitors displayed the steepest GSR decline in the commercial waterfront. These findings reveal how amenity facilities enhance the affordance of the built environment and thereby confer restorative benefits upon pedestrians.

Second, local residents and first-time visitors exhibited markedly divergent physiological response patterns in identical scenes. Local residents' GSR in community scenes was significantly lower than in all other scene types except blue–green spaces; conversely, first-time visitors' GSR was significantly elevated and more variable in community scenes. Among the local resident samples, length of residence had no significant effect on either mean GSR or within-scene change rates, indicating that the mechanism by which environmental familiarity operates is not a linearly cumulative process—that is, once an individual has established a basic cognitive schema and spatial representation of an environment, substantial stress-buffering benefits can be obtained.

Third, the study reveals a sequential exposure mechanism: participants first exposed to restorative environments maintained significantly lower mean GSR than those first exposed to stressful environments, an effect that was more pronounced for the local residents. Prior exposure to restorative environments can establish a lower physiological arousal baseline, forming a "psychological buffer", thereby enhancing individuals' arousal tolerance and psychological resilience.

Competing interests | The authors declare that they have no competing interests.

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