摘要
街道作为一种重要的城市公共空间，疗愈潜能是其社会价值的体现之一。本研究从注意力恢复理论出发，以其提出的疗愈性环境的4个特征因子——“远离性”“延展性”“迷人性”“兼容性”为依据，阐明了街道空间具有疗愈性对于高密度城市环境中居民的重要意义。研究通过将传统的疗愈性量表问卷与移动式眼动仪相结合，了解使用者在城市街道环境中能够获得的疗愈性体验，并识别出与疗愈性相关的街景元素，用以探究不同元素对人们疗愈性体验的影响程度。研究结果表明，“绿植”“人”“汽车”等是显著影响街道使用者疗愈体验的街景元素。此外，不同街景元素对疗愈环境4个特征因子的影响程度不尽相同，如；对于远离性、延展性和迷人性三个维度来说，“绿植”的影响最为重要；而对于兼容性维度来说，“人”是核心影响因素。研究结果可为归纳提升街道疗愈性的设计导则提供参考，并帮助专业人员依据不同类型街道的疗愈性侧重点制定具有针对性的设计改善思路。

关键词：疗愈性；街景元素；感知评价量表；移动式眼动仪；注意力恢复理论

ABSTRACT
The street is a type of important urban public space with multiple social values, one of which is the restorative potential. Based on the “being-away,” “extent,” “fascination,” and “compatibility” constructs of restorative environments proposed by the Attention Recovery Theory, this study elaborated the significance of restorativeness provided by street environments to people living in high-density cities. It used the traditional restorativeness scale with mobile eye trackers to explore the restorative experience provided by an urban street, and identified the specific streetscape elements related to restorativeness and the degree of their influences. The results show that “greenery,” “people,” and “cars” perform significant influences, and different streetscape elements have different degrees of influences on the 4 constructs of the restorative environment. For example, for the “being-away,” “extent,” and “fascination” constructs, the influence of “greenery” is the most important, while “people” plays the core role in “compatibility.” The findings can help professionals develop targeted design strategies to improve diverse street environments for a better restorativeness.

KEYWORDS
Restorativeness; Streetscape Elements; Perception Evaluation Scale; Mobile Eye Tracker; Attention Recovery Theory
1 Introduction

Natural environment can bring restorative experience, which is, however, usually limited to the residents in high-density cities. In this sense, it is more important for space making to help people get "healed" in urban spaces within dense built environments rather than in suburbs. Streets, as primary places for daily outdoor activities\[1\]~\[3\], may offer temporary yet repeatable restorative experiences through design interventions, which contribute largely to shaping a healthy urban environment. As a typical high-density city in China, Shanghai sees such potential in its urban street system of diverse spatial experiences\[4]\[5\] that may create convenient and continuous restorative benefits for people. Focusing on the Guokang Road in Yangpu District of Shanghai, this study used questionnaire survey with eye tracking technology to identify streetscape elements that influence the restorative experience of pedestrians, so as to provide evidence for streetscape design for restorativeness improvement.

2 Restorativeness of Urban Streetscapes

2.1 Theoretical Development

Originating from Environmental Psychology, theories of restorative environments mainly focus on probing into specific environmental experiences and features that help with the recovery of humans’ psychological, physiological, and social resources from daily exhaustion\[6]\[8\]. Early research commonly found that even spending a little time in the nature or just looking at natural scenes through a window can help recover humans’ attention\[9]\[11\] and improve emotional and mental state\[12]\[14\], significantly enhancing cognitive competence and ameliorating behaviors\[15]\[20\]. In order to leverage such benefits to guide the environmental design for restorativeness improvement, scholars have established standardized methods to evaluate restorativeness\[11]\[21]\[22\]. Most of these studies employed multi-dimensional psychological scales based on psychological constructs of restorative environments to evaluate people’s recovery through questionnaire surveys. There have been two mainstream theories of restorative environments: Attention Restoration Theory (ART)\[15]\[17\] proposed by Rachel and Stephen Kaplan and focusing on attention fatigue, and the Stress Reduction Framework proposed by Roger S. Ulrich\[16]\[18\] and focusing on physiology and emotion decline (Fig. 1). Particularly, the former summarizes 4 constructs of restorative environments, namely being-away, extent, fascination, and compatibility, which have become the theoretical foundation for restorativeness evaluation scales\[15\], including the Perceived Restorativeness
2.2 A Review on Methods of Restorativeness Evaluation

Most early research performed visual evaluation of landscapes via images, videos, 3D models, or VR scenes\(^{[14]}\), and the Restorative Component Rating Scale (RCS\(^{[11]}\)). However, these tools can be hardly used to identify specific environmental features related to restorativeness as they quantify merely the restorativeness perception of the participants\(^{[21]}\).

The process of urbanization has encouraged more and more studies in recent years to explore the restorative potential of natural elements in built environments\(^{[24]-[27]}\). Some suggest that a restorative environment does not always satisfy all the 4 constructs of ART\(^{[28]}\). Moreover, urban spaces such as streets\(^{[29]}\) and squares\(^{[10]}\) that are designed of these constructs can provide restorative experience\(^{[31],[32]}\). As frequently used places in people’s everyday life, streets are designed for passing through—in comparison to other types of urban spaces (e.g. parks and squares) to stay in. Studies on restorative streetscapes proved that people’s restorative experience correlates negatively with the height of buildings in the streets and the street’s entropy value (describing the disorder of a street environment)\(^{[13]}\), while positively with the quantity of street trees and planting beds\(^{[29]}\). However, street environment is complex. Existing research mainly focuses on individual streetscape elements (buildings, street trees, etc.) or street characteristics (extensibility, complexity, and skyline changeability of the street interface, etc.), and efforts that systematically examines all the streetscape elements are absent.

2.2 疗愈性评价方法回顾

早期的景观视觉评价大多以图片、视频、三维立体模型或虚拟现实场景等作为视觉媒介\(^{[34]}\), 要求参与者以偏好排序、打分等形式进行评估。但无论是图像还是模型, 都可能因为缺乏真实感而影响评价。
where the evaluations were based on participants’ preference ranking \[^{33}\] and scoring \[^{36}\]. However, the lack of authenticity of such visual media might lead to a low accuracy of evaluation \[^{37}\]. In recent years, this problem has been addressed by the advance of eye tracking technology which helps discover the relations between visual perception and specific environmental agencies by capturing the fixation points and movement tracks of eyes \[^{38} - ^{40}\]. It has widely evidenced that human’s visual preference is closely related to the restorativeness of environment \[^{11} - ^{31} - ^{41}\], and the fixation duration positively correlates to visual preference \[^{42} - ^{44}\] that inspires scholars to further use eye trackers in ART-based research. By capturing the movement track of fixation point and taking the fixation frequency to indicate the viewer’s visual preference, the environmental elements related to restorativeness can be identified \[^{11} - ^{31} - ^{41} - ^{44}\]. For example, Rita Berto et al. found that environments with varied level of restorativeness may result in different eye movements \[^{41}\]. Other researchers confirmed the correlations between high-frequency fixation points recorded by eye trackers and the restorativeness of corresponding landscape elements \[^{45}\] in small urban spaces.

3 Study Methods

This study explores the relations between restorativeness perception and streetscape elements in the real world by adopting both qualitative and quantitative methods—utilizing a restorativeness evaluation scale supported by eye tracking technology. This is based on the prerequisite that when people are working on questions of a scale, their thinking would stimulate the eye movements \[^{46} - ^{48}\] and the fixation points captured by the eye tracker can be considered the restorative streetscape elements in the environment.

3.1 Self-Reporting Evaluation on Restorativeness Perception with Questionnaire

This study employed the RCS developed by Karin Laumann et al. \[^{11}\] to evaluate the restorativeness perception, because confirmatory factor analysis has proved that the factor structure of RCS better echoes the 4 constructs in ART. Besides, RCS adopts a consistent wording in describing the 4 constructs, which helps participants better understand the meaning of scale questions for a higher accuracy of evaluation.

The questionnaire used in this study consisted of 2 parts: the first part adapted 15 questions of the original RCS that
### Table 1: The restorative component scale used in this study

| Constructs of a restorative environment | Evaluation questions to each restorative construct |
|----------------------------------------|---------------------------------------------------|
| **Being-away (B)**                     |                                                   |
| B1                                     | 这里让我能够暂时忘记工作和日常的生活中的烦恼。 When I am here I feel free from work and daily routine. |
| B2                                     | 这里让我能够暂时忘记他人的要求和期望带来的压力。 When I am here I feel free from other people's demand and expectations. |
| B3                                     | 这里让我能够暂时忘记所承担的责任与义务。 When I am here I do not need to think of my responsibilities and obligations. |
| **Extent (E)**                         |                                                   |
| E1                                     | 这里的所有东西都是互相联系的。 The elements here go together. |
| E2                                     | 这里的所有东西都很好地融入环境之中。 The existing elements belong to here. |
| E3                                     | 周围的环境整体上是连贯的。 The surroundings are coherent. |
| **Fascination (F)**                    |                                                   |
| F1                                     | 这里有很多我要探索的东西。 There is plenty to discover here. |
| F2                                     | 这里有很多令我感到好奇的东西。 This setting has many things that I wonder about. |
| F3                                     | 这里有很多吸引我的东西。 There are many objects here that attract my attention. |
| F4                                     | 这里有很多使我流连忘返。 There is plenty that I want to linger on here. |
| F5                                     | 我感到深深地沉浸在周围的环境里。 I am absorbed in these surroundings. |
| **Compatibility (C)**                  |                                                   |
| C1                                     | 这里让我有机会去做我喜欢做的事情。 The environment gives me the opportunity to do what I like. |
| C2                                     | 我能够解决在这里出现的问题。 I can handle the kinds of problems that arise here. |
| C3                                     | 我能够很快地适应周围的环境。 I rapidly adapt to this setting. |
| C4                                     | 我想做的事情能够在这一环境中得到实现。 There is an accordance between what I like to do and this environment. |

**Note:**
The scale is adapted from Ref. [11].

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are applicable to streetscape evaluation, corresponding to the 4 constructs in ART (Table 1). Participants were required to score the consistency degree of the description in each question to their own perception with 0 ~ 6 points: 0 means not consistent at all and 6 points means totally consistent; and the second part collected participants' personal information, including gender, age, and occupation / profession.

### 3.2 Identification of Restorative Streetscape Elements with Eye Tracking Technology

The study employed the Tobii Pro Glass 2 mobile eye tracker...
provided by the Experimental Center of Ergonomical Intelligence and Environmental Behavior of Tongji University to collect data of eye movement tracks, including videos and fixation points with location and time information. The collected videos were first framed into images for semantic segmentation by machine learning. Then the results were matched with the coordinates of the fixation points to locate the environmental elements that the participant looked at (Fig. 2). These elements were further compared with the evaluation results of the RCS to calculate the cumulative fixation frequency of each type of element. The elements of higher fixation frequency were considered the restorative components within the investigated environment[11],[31],[41]-[44] (Fig. 3).
3.3 Research Site Selection

Due to a lack of reference adopting similar methods, this study proposed its own metrics in research site selection—a street of 300 ~ 1,000 meters (considering that the participants should finish the questionnaire in 3 ~ 5 minutes), with clear starting and end points, and the types and elements of frontage can be easily identified. The Guokang Road was selected: as a commuting urban street along which there are a number of educational, research, and administrative workplaces (Fig. 4), it stretches for 720 meters, taking 8 minutes to walk through, and the streetscape is largely defined by greenery and fences, with a few shops in its middle section (separated from the lanes by hedges). Further, based on the locations of bus stops and the frontage types along the street, as well as a preliminary site investigation, a 380-meter-long section where the working people visit most frequently was chosen for this experiment. This section covers all typical frontage types of the street, and allows participants to finish the questionnaire while walking through it within 5 minutes (Fig. 5).

3.4 Participant Selection

Participants recruited on-site on Guokang Road for this
3.4 Choosing Participants

Participants were sought at the Onaka Road site. They were mostly aged between 25 and 55, who are prone to mental fatigue and pressure. Considering that in a safe environment, people might perceive higher restorativeness when they are alone, only those participants who were alone were selected. In the end, totally 15 males and 16 females participated in the experiment; 19 of them are occupationally / professionally associated with planning, landscape design or architecture. 29 valid samples were finally collected.

3.5 Experiment Process

The experiment was carried out during lunch hours (11:00 ~ 14:00) from May 6 to 10 (all were working days) in 2019, the weather was sunny with moderate temperature and good air quality. Participants were asked to test and calibrate the eye tracker before the experiment. During the formal measurement, the participants were required to walk casually through the street, accompanied with a researcher asking them the RCS survey while walking behind them to avoid visual distractions. The eye tracker started recording videos as the survey began, and ended when it was finished.

4 Data Analyses

The data of the 29 completed RCS questionnaires were verified in internal consistency. The ANOVA analyses (in terms of gender, age, and occupational / professional information) revealed that no difference was found in the competence of restorativeness perception among the participants, proving that the data were valid and reliable (Table 2). The capture ratio for eye movement of the 29 participants ranged from 2% to 90%, with an average of 53% (SD = 28.5%), and those under 20% were eliminated, referencing previous research. Finally, 25 valid samples were retained.
4.1 选取路段街景的疗愈性

问卷结果（表3）显示，被试者对选取路段现状街道环境的疗愈性评价适中（总平均分3.50分），4个特征因子中远离性（3.05分）和迷人性（2.87分）得分低于延展性（4.03分）和兼容性（4.06分）得分。选取路段是一条主要服务于周边工作人群的通勤道路，与工作紧密相关是导致环境远离性得分较低的主要原因，这一点在B3项的评价结果（2.60分）上体现得尤其明显。迷人性因子的5个评价小项均得分偏低，特别是对街道环境的好奇心（F1项，2.60分）和探索欲（F2项，2.72分）的评价。这是由于国康路两侧界面形式较为单一，缺少沿街店铺、特色景观等可供注视、停留或进行其他活动的界面，故而对行人的吸引力有限。

### 表3: 实验路段街景疗愈性RCS评价结果（n=25）

| 子特征因子 | 平均得分 | 特征因子 | 平均得分 |
|------------|----------|----------|----------|
| 远离性（B） | | 延展性（E） | | 迷人性（F） | | 兼容性（C） | |
| B1 | 3.24 | E1 | 4.48 | F1 | 2.60 |
| B2 | 3.32 | E2 | 4.16 | F2 | 2.72 |
| B3 | 2.60 | E3 | 3.44 | F3 | 3.04 |
| B4 | 3.24 | E4 | 4.16 | F4 | 3.16 |
| C1 | 3.48 | E5 | 3.44 | F5 | 3.16 |
| C2 | 4.12 | E6 | 3.44 | C3 | 3.80 |
| C4 | 4.84 | E7 | 3.44 | C4 | 3.80 |

4.1 Restorativeness of the Streetscape of the Selected Section

The questionnaire results (Table 3) showed that the participants’ evaluation on the restorativeness of the street section was moderate (with an overall average of 3.50 points). Among the 4 constructs, “being-away” (3.05 points) and “fascination” (2.87 points) scored lower than “extent” (4.03 points) and “compatibility” (4.06 points). The low score in “being-away” may result from that the street is surrounded by workplaces and the walking might evoke the participants’ commuting and working experience, especially affected their scoring in the sub-construct associated with “responsibility and obligation” (B3, 2.60 points). In addition, the scores of all the 5 sub-constructs in “fascination” were low—particularly in “curiosity to the street environment” (F1, 2.60 points) and “desire to explore the environment” (F2, 2.72 points)—because the monotonous streetscape of the selected section less encouraged the participants to look at or stay in.
4.2 Identification of Restorative Streetscape Elements

With coordinates recorded by the eye tracker, the fixation points were positioned in each video frame, and 12 types of streetscape elements related to people’s restorative experience were identified through semantic segmentation and by screening out “road” and “sidewalks”—they took a larger proportion in the whole image that might impact the results (Fig. 6). The results showed that the top 3 elements that participants looked at were “greenery” (39.33%), “people” (26.25%), and “walls” (10.54%), followed by “cars” (8.52%), “bicycles” (5.42%), “buildings” (4.47%), “fences” (2.61%), and “slight height variations” (1.57%).

4.3 Influencing Mechanism of Streetscape Elements on Restorative Constructs

The researchers divided each video into 4 segments by the participants’ evaluation to each construct, and audited the percentage of fixation frequency for each streetscape element in each segment, in order to identify the influencing elements to each construct and the corresponding mechanism. The results showed a significant variety in the influence degree (Fig. 7):
“Greenery” was the most frequently recorded fixation element during the evaluation of “being-away” (33.19%), “extent” (42.61%), and “fascination” (43.03%), showing the highest effect on restorativeness. For the construct of “compatibility,” “people” (31.57%) was more important than “greenery” (27.18%), because “compatibility” measures the satisfaction degree of a street environment to people’s needs, and streets are main places accommodating citizens’ social interactions. “Walls,” “buildings,” and “fences” were the most influencing elements to the constructs “being-away,” because the greenery can be seen through the fencing-walls along the selected section; besides, a group of red-brick college buildings on the one side are distinctively attractive, which can arouse the working group’s memories and affections to their school life. The sum percentage of fixation frequency of “cars” and “bicycles” increased significantly during the evaluation of “extent” compared with the other 3 constructs. This is because according to the connectedness and scope defined as 2 sub-items of “extent”, “cars” and “bicycles” are “passing-through” elements that temporarily occur in a streetscape and may decrease the participants’ restorativeness perception of the streetscape.

4.4 The Positive and Negative Effects of Restorative Streetscape Elements

Assisted with SPSS 26.0, the Pearson correlation analysis between the evaluation results and the proportion of fixation frequency of each element revealed the positive or negative effects on restorativeness perception. Results showed that “slight height variations” and “greenery” would help augment participants’ restorative experience, while “bicycles,” “fences,” “buildings,” “walls,” “cyclists,” and “cars” would decline such an experience to varying extents. Compared with the other elements with high fixation frequency shown in Figure 6, the element of “people” presented neither evident positive nor negative correlation with any construct, which might be explained by different evidences by existing empirical studies: some argue that the restorativeness perception on “people” depends mainly on whether the investigated environment is safe—being in a safe environment, the participant can get better restorative experience when the place is less crowded; others hold that the characters of participants determine their perception of “people,” which would influence their restorative experience in the environment. For another interesting finding, “cyclists,” though positively correlating to "pressure from others' demands and expectations" (B2) and negatively to “continuous environment” (E3), did not get a high fixation frequency in this experiment.
5 Conclusion and Discussion

In recent years, the restorative potential of street environment has attracted increasing attention of the academia[29][33], but systematic research on the restorative elements is absent. In response to the urgent needs of daily restorative environment against the current backdrop of high-density urban development, this study attempted to examine the restorativeness of urban streets as an everyday place for citizens, and explored the relations between the intangible restorativeness perception and the tangible streetscape elements by combining qualitative and quantitative methods, so as to inspire design practices to improve the restorativeness of streetscapes.

The study found that “greenery” was the focal streetscape element when participants were evaluating the restorativeness, indicating that “greenery” played an important role in providing restorative experience within streetscapes, corroborating the significant restorativeness of green natural elements proved in previous studies[8][11]. Further analyses in this study manifested that the importance and influential mechanism of different streetscape elements on the 4 ART constructs varied, including the significant influence of “greenery” on “being-away,” “fascination,” and “extent,” the influence of “people” on “compatibility,” and the increasing influence of “cars” on “extent” and “compatibility.” All these findings may support landscape planning and design practices with an empirical basis for targeted restorativeness in specific cases.

However, except for “greenery,” “people,” and “cars,” there has been no existing research paying attention to the other 9 elements or drawing similar conclusions to this study. This may be due to the lack of existing research on the street environment,
and the failure of the “questionnaire-and-eye-tracking survey” method in describing the qualitative attributes of streetscapes (e.g. complexity, openness). Therefore, it is necessary to establish a restorativeness evaluation framework which examines both physical and qualitative attributes of streetscape elements. In addition to RCS, future analysis may also adopt more scales from other related theories to expand the research domain of streetscape restorativeness. Linking self-reporting perception and technical identification of physical environment, this method can also be applied to other environmental psychology studies.

The research methods and technologies employed in this study need to be improved in the future: the investigated street mainly serves commuters and the streetscape is homogeneous in frontage type and form; as the participants’ perceptions might vary with street characteristics and types (e.g. commercial streets, landscape streets), the influence distributions among the 4 constructs of the adapted RCS may change accordingly. Therefore, the conclusion in this study is not yet widely applicable, and more diverse restorativeness improvement strategies to varied street environment are required. The study did not eliminate the contribution of the proportion of each element in a participant’s vision to the percentage of their fixation frequency ($p = 0.05$), thus causing errors in identifying the restorative streetscape elements. It should be avoided in future research through improved experimental methods for more accurate identification of the correlations of restorative streetscape elements with high-frequency fixation points.

In conclusion, this study reinforces the significance of daily urban environment in providing restorative experience for citizens by focusing on street environment. Manifesting the positive and negative effect of different street elements on the restorative experience, the findings of this study would offer guidance for the design practice that improves restorativeness performance of different street environments. This study also evidences the social potential a street environment should perform but now has less been explored or recognized, as well as that many other urban places can also offer restorative experience for people as what natural environment does. LAF

**NOTE**

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