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疗愈性街景元素识别与评价研究

AN EXPLORATIVE STUDY ON THE IDENTIFICATION AND EVALUATION OF RESTORATIVE STREETSCAPE ELEMENTS

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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也不尽相同，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

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1 引言

通常而言，自然环境能够带来疗愈体验，但高密度城市的空间及资源供给极大限制了城市居民与自然环境的接触。对于高密度城市空间营造而言，在日常场景中满足居民的疗愈性体验需求比为其提供前往郊野的机会更为重要。街道是人们在“外界”生活的主要空间载体[1]~[3]，利用街道环境为人们提供短暂而多次的疗愈体验显然更加实际。因此，街道环境中任何可能通过设计手段赋予或增强的疗愈潜能，对塑造有利于健康的城市环境都有着巨大的价值。上海是中国典型的高密度城市，人口规模庞大，城市资源紧张。依托城市支路形成的丰富多样的街道空间[4][5]具备为居民提供便捷、连续的疗愈体验的潜力。研究选取上海市杨浦区支路国康路作为研究对象，通过问卷调查和眼动追踪相结合的方法，探究了影响行人在街道环境中获得疗愈性体验的街景元素，以寻求通过设计手段提升街道环境疗愈性的方法。

2 城市街景疗愈性

2.1 相关理论发展

疗愈环境理论起源于环境心理学，侧重于探究能够帮助人们恢复在日常生活工作中消耗的心理、生理和社会资源的特定环境体验及特征[6]~[8]。早期的疗愈环境理论研究普遍认为，即使仅与自然环境进行极短的接触或仅向窗外眺望自然景色，也能够帮助人们提升注意力[9]~[11]，改善情绪和精神状态[12]~[14]，从而显著提升认知能力、改善行为表现[15]~[20]。为将人们在环境中获得的疗愈性体验应用于以疗愈为导向的环境设计，诸多学者曾尝试建立标准化的疗愈性评价方法[11][21][22]。这些研究大多以疗愈环境的心理学构成为基础构建多维度心理学量表，通过问卷获得使用者对环境疗愈性的评价。蕾切尔与斯蒂芬·卡普兰提出的聚焦于注意力衰竭的“注意力恢复理论”（ART）[15][17]和罗杰·S·乌尔里希[16]~[18]提出的聚焦于生理和情绪的负面变化的“压力舒缓理论”是两大主流疗愈环境理论（图1）。其中，ART所总结的疗愈环境的4个特征因子——远离性、延展性、迷人性和兼容性，成为了构建疗愈性评价量表的主要理论支撑[15]，相关量表包括疗愈感知量表[22]和疗愈

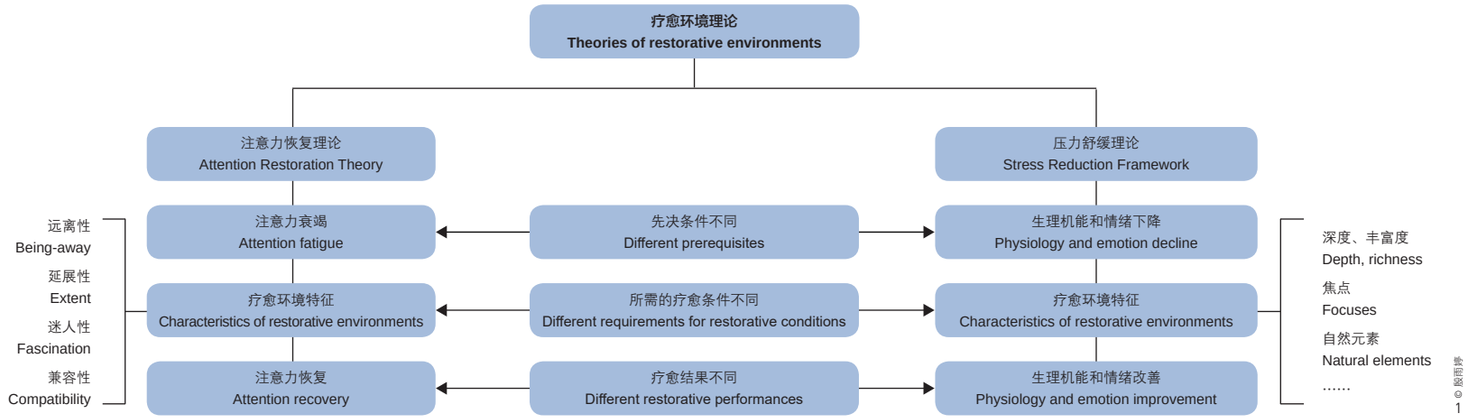
1 Introduction

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



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因子量表（RCS）[11]等。值得注意的是，此类量表多以数字量化评价被试者的心理状态[23]，单纯使用这些量表无法识别出与疗愈性相关的具体环境特征。

近年来，在城市化的影响下，越来越多的研究开始探索建成环境中自然元素的疗愈潜能[24]~[27]。已有研究表明，疗愈性环境不必同时具备ART的4个特征因子[28]；经过精心设计的具有这些特征因子的街道[29]、广场[30]等城市空间同样能够提供疗愈性体验[31][32]。相较于公园、广场等公共场所，尽管人们在街道上停留的时间通常较短，但使用街道的频率却明显更高。国外针对街景开展的疗愈性研究发现，街道两侧的建筑越高，且街道熵值（街道环境中各元素的混乱度）越大，人们获得疗愈性体验的可能性越小[33]。此外，行道树及种植池数量的增加也能显著提高街道的疗愈潜能[29]。然而，由于街道环境的复杂性，这类评价研究多针对建筑物、行道树等特定街景元素或沿街界面延伸性、复杂性和天际线变化等特定街道环境特征展开，未能对街景元素进行系统的考量。

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[35]、打分[36]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[37]而影响评价

1. 两种主流的疗愈环境理论

1. Two mainstream theories of restorative environment

Scale[22] 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[23].

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[30] 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)[33], 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 A Review on Methods of Restorativeness Evaluation

Most early research performed visual evaluation of landscapes via images, videos, 3D models, or VR scenes[34],

结果的准确性。近年来飞速发展的眼动追踪技术能够通过捕捉人眼球的注视点和运动轨迹，有效地建立视觉感知与环境中特定媒介之间的联系[38]~[40]，为突破这一局限性提供了技术基础。学界已有充足证据表明，人们对环境的视觉偏好与环境疗愈性密切相关[11][31][41]，注视时长与视觉偏好的正相关性[42]~[44]则引导学者们进一步探索眼动仪在ART相关研究中的应用。他们尝试运用眼动追踪技术捕捉疗愈性环境中人们注视点的运动轨迹，以注视频次表征视觉偏好，由此发掘与疗愈性相关的环境元素[11][31][41]~[44]。例如，丽塔·博托等人发现疗愈性不同的环境会引发不同的眼球运动模式[41]；此后又有研究在探寻小型城市公共空间中与疗愈性相关的景观元素时，进一步证实了眼动仪所记录的高频注视点与对应元素的疗愈性之间的关系[45]。

3 研究方法

为了在真实环境中系统地理解疗愈感知和街景元素之间的关系，本研究尝试在已有方法的基础上，将基于疗愈性评价量表的定性方法与基于眼动追踪技术的定量方法结合使用。已有研究认为，当使用疗愈性评价量表来调查人们的疗愈感知时，人们大脑对量表问题的思考将会带动眼球运动[46]~[48]，而该过程中眼动仪捕捉到的注视点即可表征街道环境中与疗愈性有关的街景元素。

3.1 主观疗愈性感知评价——问卷调查法

本研究选取卡琳·劳曼等人[11]制定的RCS作为主观疗愈性感知的评价工具。验证性因子分析结果表明，相较于其他基于ART的疗愈性量表，RCS的因子结构与ART提出的疗愈环境特征因子更为贴合，且描述ART4个特征因子的措辞方式一致，更加有利于人们理解量表含义，作出准确评价。

问卷第一部分在原RCS基础上略作修改，保留了其中15项适用于街道环境评价的问题，分别评价ART提出的4个疗愈环境特征因子（表1），被试者用0~6分来描述每个问题与自身实际感知的相符程度，完

where the evaluations were based on participants' preference ranking[35] 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 are

表1：本研究中使用的疗愈因子量表
Table 1: The restorative component scale used in this study

疗愈环境特征因子 Constructs of a restorative environment	疗愈性因子评价问题 Evaluation questions to each restorative construct	
远离性（B） 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.
延展性（E） 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.
迷人性（F） Fascination (F)	F1	这里有很多我想要探索的东西。 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	这里有许多事物使我流连忘返。 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中。 I am absorbed in these surroundings.
兼容性（C） 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.

注
量表内容改编自参考文献[11]。

NOTE
The scale is adapted from Ref. [11].

全不符为0分，完全符合为6分；第二部分采集了参与者的性别、年龄及专业背景等个人信息。

3.2 客观疗愈性街景元素识别——眼动追踪技术

研究采用由同济大学人因智能与环境行为实验中心提供的Tobii Pro Glass 2移动式眼动仪捕捉被试者的眼球运动轨迹，所采集的数据包括动

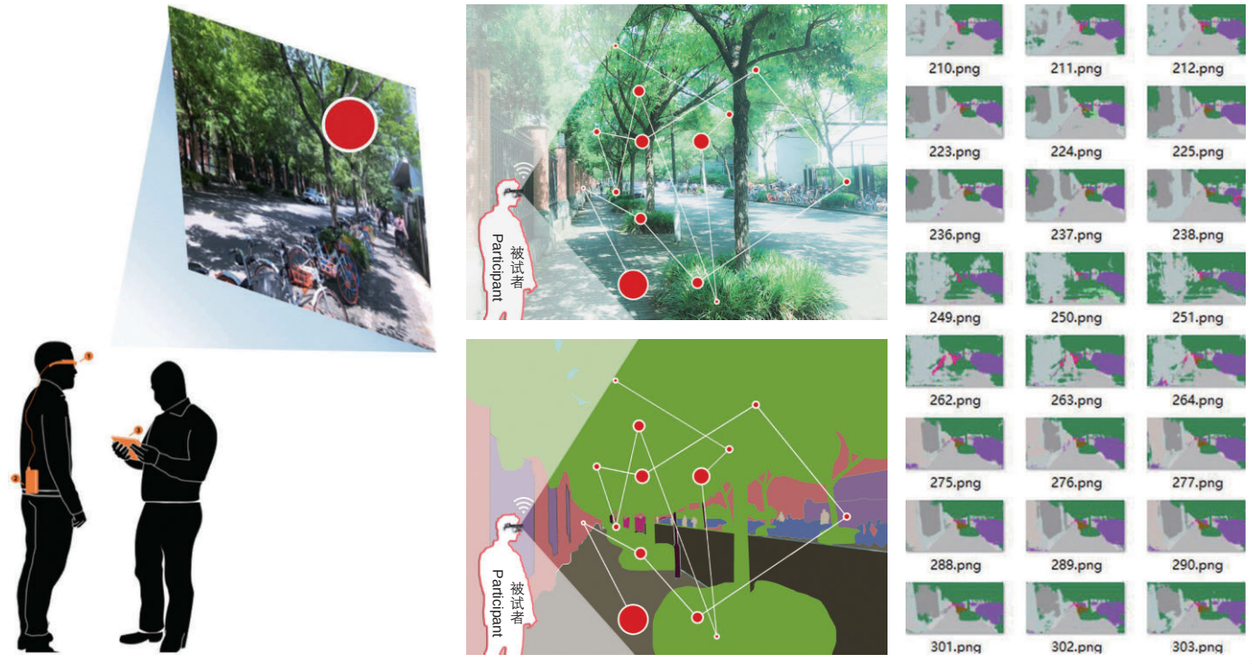
applicable to streetscape evaluation, corresponding to the 4 constructs in ART (Table 1). Participants were required to score the consistency degree of the description in each question to their own perception with 0 ~ 6 points: 0 means not consistent at all and 6 points means totally consistent; and 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

2. 视频图像经过语义分割后进行注视点匹配
3. 研究方法框架

2. Semantic segmentation and fixation point match of the video images
3. The study method framework



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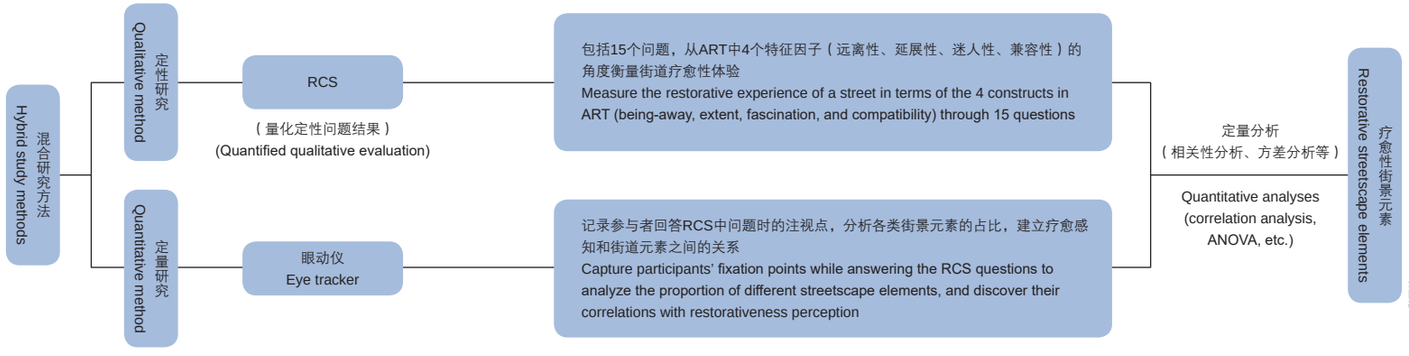

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态视频及带有坐标和时间信息的注视点。研究采用基于机器学习的图像语义分割技术，将视频输出为图像后进行画面分割，再与注视点的坐标进行匹配，找到每一帧画面中参与者注视的环境元素（图2）；随后将上述匹配结果与RCS中疗愈性问题的评价结果进行比对分析，了解在参与者回答有关街道疗愈性问题的过程中各类街景元素被注视的累积频次，其中的高频注视点即可表征研究环境中与疗愈性密切相关的街景元素[11][31][41]~[44]（图3）。

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).

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4

3.3 Research Site Selection

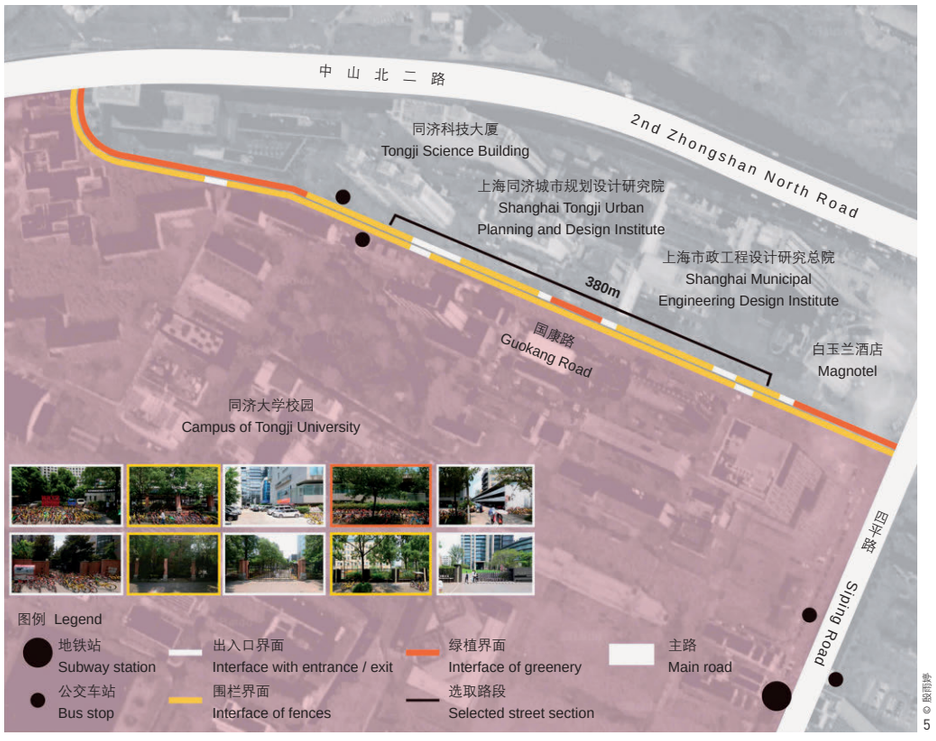
Due to a lack of reference adopting similar methods, this study proposed its own metrics in research site selection—a street of 300 ~ 1,000 meters (considering that the participants should finish the questionnaire in 3 ~ 5 minutes), with clear starting and end points, and the types and elements of frontage 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 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 experiment were workers aged between 25 and 55, who are

3.3 确定研究地点

由于目前在真实场景中综合运用问卷调查和眼动追踪技术的研究较少，结合单次问卷调查所需时长（3~5分钟），研究宜选择长度为300~1 000m，具有明确的起、终点，两侧沿街界面功能类型明确、元素组成较为简单的街道环境进行实验。国康路两侧主要为教育科研机构与行政办公场所，是一条以通勤功能为主的城市支路（图4），长约720m，全程步行约需8分钟；沿街界面主要由植被和围栏构成，中段毗邻少量店铺（与路面之间有绿篱分隔），界面构成较为均质。根据沿路公交站点的分布位置，结合街道两侧的建筑功能及前期的场地调研分析，最终选择人群出现较为频繁的区域作为实验路段。该路段涵盖



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5

4. 国康路实景
5. 研究地点（地图来源：百度地图、百度街景）

4. The real environment of Guokang Road
5. The research site (Map sources: Baidu Map, Baidu Streetscape)

① 本研究中，“有效样本”指完成了所有量表评价项且提供了被试者完整背景信息的样本。

② 由于仪器受室外光线及无线信号影响较大，即使经过仪器校准和行走适应，不同被试者的眼动捕捉率仍然可能存在较大差异。

① "Valid samples" in this study are those with completed evaluation results and participants' individual information.

② Despite device calibration and adjustment, the capture ratio for different participants may still vary because the eye trackers are also subject to outdoor light and wireless signals.

表2：参与者组间差异分析显著性值（n=25）
Table 2: Significance values by ANOVA analyses on the participants (n = 25)

	B1	B2	B3	E1	E2	E3	F1	F2	F3	F4	F5	C1	C2	C3	C4
性别 Gender	0.730	0.884	0.388	0.693	0.513	0.513	0.329	0.950	0.807	0.980	0.489	0.053	0.515	0.880	0.150
年龄 Age	0.497	0.399	0.010	0.268	0.417	0.208	0.896	0.262	0.519	0.259	0.142	0.297	0.350	0.113	0.303
专业背景 Occupational / professional information	0.398	0.987	0.26	0.746	0.284	0.133	0.322	0.653	0.953	0.062	0.263	0.964	0.753	0.693	0.757

整条路段中所有界面种类，具有代表性；长度约380m，步行通过时长与答题时长基本吻合（图5）。

3.4 选择参与者

参与者由研究人员在国康路现场招募，主要为承受较大生活压力、易产生心理疲劳等问题的工作人群（25~55周岁）[50]。因已有研究发现，在保证安全的前提下，人们在独处时获得疗愈体验的可能性更高[51]，本次试验仅选择独自出行者参与。最终共31人参与实验，男性15人，女性16人，其中具有专业背景的（指工作或学习背景与规划、景观和建筑有关）19人。最终筛选出有效样本①29份。

3.5 实验过程

实验于2019年5月6~10日（均为工作日）午休时间（11:00~14:00）展开，实验日天气均温度适宜、无雨且空气质量良好。参与者在佩戴移动式眼动仪后需首先进行校准与行走适应，以保证在正式实验中所收集数据的准确性。校准成功并适应后，被试者以自然状态向前方行走，研究人员随行其后进行RCS的提问，以免进入被试者视线范围。眼动仪从量表提问开始时进行视频录制，结束时终止。

4 数据分析

实验获得的29份RCS问卷数据均通过了内部一致性信度检验[52]。对问卷数据进行组间（性别、年龄及是否具有相关专业背景）差异分析，发现29名被试者在疗愈性体验上不存在感知能力差异，说明数据有效可靠（表2）。眼动仪对29名被试者的眼动捕捉率为2%~90%②，平均值为53%（标准差为28.5%）。结合前人研究经验[53]，将捕捉率低于20%的样本剔除，最终保留有效样本25个。

prone to mental fatigue and pressure[50]. Considering that in a safe environment, people might perceive higher restorativeness when they are alone[51], only single passers-by 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 samples① 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 questions 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[52]. 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%②, with an average of 53% (SD = 28.5%), and those under 20% were eliminated, referencing previous research[53]. Finally, 25 valid samples were retained.

表3：实验路段街景疗愈性RCS评价结果（n=25）
Table 3: The evaluation results of RCS on the streetscape restorativeness of the selected section (n = 25)

	远离性（B）Being-away (B)			延展性（E）Extent (E)			迷人性（F）Fascination (F)					兼容性（C）Compatibility (C)			
	B1	B2	B3	E1	E2	E3	F1	F2	F3	F4	F5	C1	C2	C3	C4
子特征因子平均得分 Mean score of each sub-construct	3.24	3.32	2.60	4.48	4.16	3.44	2.60	2.72	3.04	2.84	3.16	3.48	4.12	4.84	3.80
特征因子平均得分 Mean score of each construct	3.05			4.03			2.87					4.06			

6. 各街景元素对应的注视累积频次占比

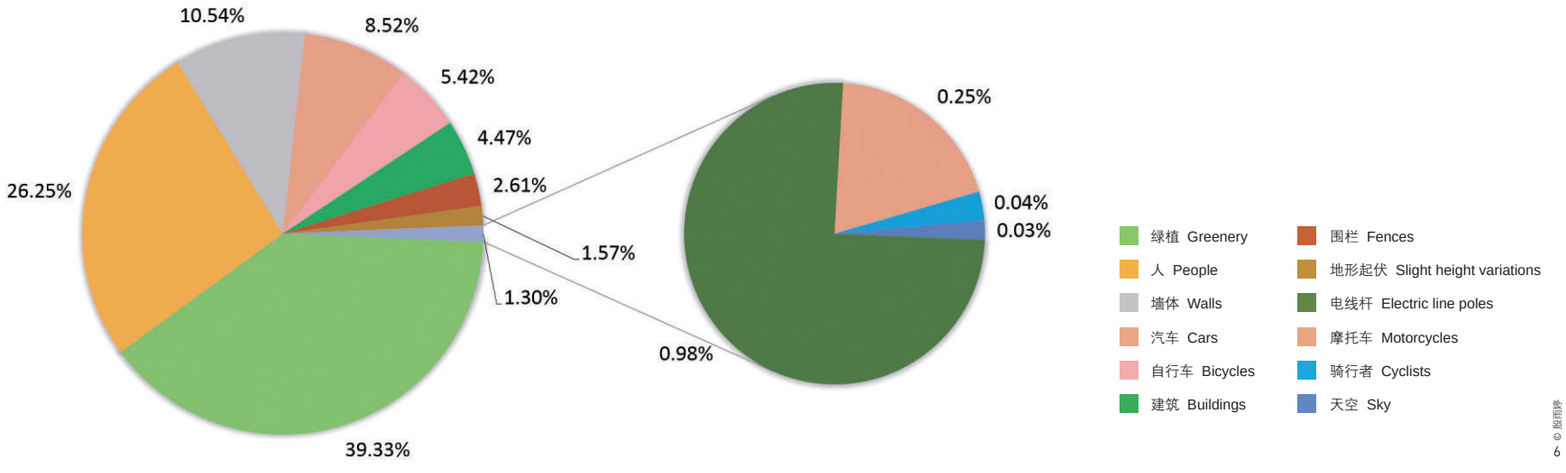
6. The percentage of the cumulative fixation frequency for each streetscape element

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。

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 obiligation" (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.



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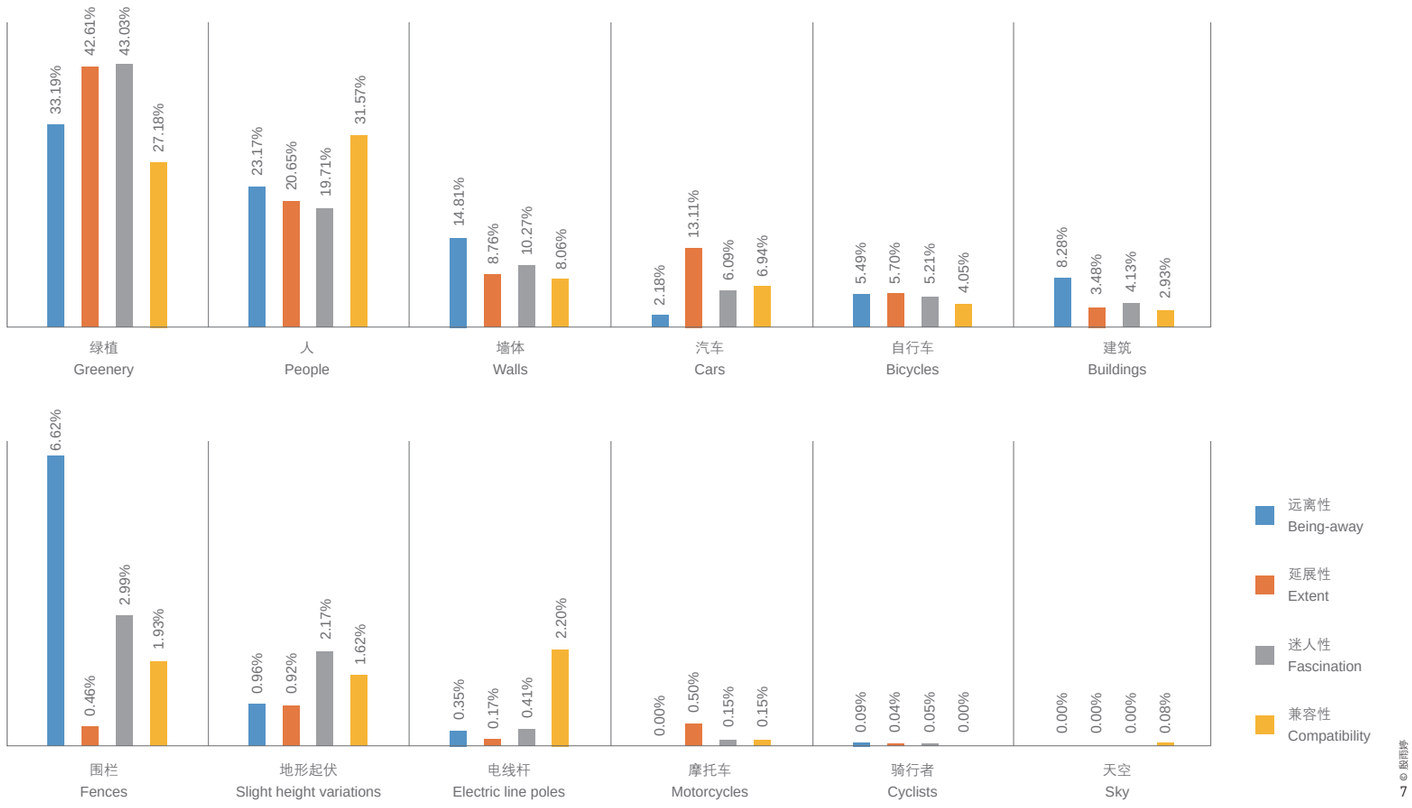
6



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7

7. 各特征因子评价过程中各类街景元素的注视频次占比

7. The percentage of fixation frequency for each streetscape element during the evaluation of each construct

4.2 疗愈性街景元素的识别

根据眼动仪所记录的注视点坐标信息将其在视频帧画面中定位，经语义分割并剔除占画面面积比例过大的“道路”与“人行道”元素后，得到12类与疗愈体验相关的街景元素（图6）。结果显示，被试者在进行疗愈性评价时，注视“绿植”的百分比最高（39.33%），其次为“人”③（26.25%）、“墙体”（10.54%）、“汽车”（8.52%）、“自行车”（5.42%）、“建筑”（4.47%）、“围栏”（2.61%）及“地形起伏”（1.57%）等，说明实验路段内“绿植”“人”“墙体”是对疗愈性体验影响最大的三类街景元素。

4.3 街景元素对疗愈环境特征因子的影响机制

研究人员按照被试者回答量表中4个特征因子相关问题的起止时间将视频切割为4段，对每一时间段中各类街景元素的注视频次进行统计，以进一步探索影响每个特征因子的街景元素及具体的影响机制。结果显示，各类街景元素对各因子的影响程度存在差异（图7）。其中，在评价远离性、延展性和迷人性的过程中，“绿植”的注视

③ 根据语义分割技术所依据的训练模型分类标准，此处的“人”专指街道空间中未使用交通工具，或站立或行走或坐的人，故而与“骑行者”为两类不同的街景元素。

③ According to the classification standard of the training model used in semantic segmentation, "people" here refers to people standing, walking, or sitting. "People" and "cyclists" thus are two different types of streetscape elements.

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”③ (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):

频次占比依次为33.19%、42.61%和43.03%，在所有元素中最高，是影响这三个因子的最主要的街景元素；但对于兼容性，“人”（占比31.57%）的影响则比“绿植”（占比27.18%）更大，这主要是由于兼容性衡量的是街道环境对人们需求的满足程度，进行必要的社交活动是人的一种内在需求，而社会交往则是街道空间承载的主要功能之一[54]。“墙体”“建筑”“围栏”元素在远离性评价中的注视频次占比明显高于其他三个因子，这是由于选取路段两侧多为透绿性较高的栅栏围墙，且其中一侧为校园内的红砖建筑，外观优美且具有年代感；校园作为与人们的特殊记忆或情感密切相关的一类场所[55]，也能够激发已步入社会的工作人群的回忆和遐想。此外，“汽车”“自行车”两类元素在延展性评价中的注视频次占比之和较其它三个因子显著增加。结合延展性因子中包含的连贯性和范围两个子因子[56]可以推测，“汽车”“自行车”为暂时存在的通过性元素，会影响街道环境内部元素之间的协调性，从而影响人们的疗愈性感知[57]。

4.4 疗愈性街景元素影响的正负性

利用SPSS 26.0软件对疗愈性感知评价结果与对应的注视点元素百分比进行皮尔逊相关性分析，以正、负相关性表征各街景元素对环境疗愈性感知的促进或遏制影响，发现“地形起伏”及“绿植”能够促进被试者获得疗愈性体验；“自行车”“围栏”“建筑”“墙体”“骑行者”“汽车”元素会不同程度地阻碍被试者获得疗愈性体验（表4）。对比图6的结果可知，在注视频次占比较高的几类元素中，“人”与任何疗愈性因子的正、负相关性皆不显著。部分已有的实证研究表明，对于环境中“人”这一元素的疗愈性与被评价的环境是否安全有关，在保证安全的前提下，被试者在人少的环境中能够获得更好的疗愈体验[51][58][59]；同时，也有研究认为被试者本身的性格会影响他们对环境中“人”这一要素及疗愈性体验的感知[59]。此外，相关性分析中出现的“骑行者”（对B2有促进作用，对E3有阻碍作用）却并非本次实验中注视频次较高的街景元素。

“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[54]. “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[55]. 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”[56], “cars” and “bicycles” are “passing-through” elements that temporarily occur in a streetscape and may decrease the participants’ restorativeness perception of the streetscape[57].

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 (Table 4). 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[51][58][59]; others hold that the characters of participants determine their perception of “people,” which would influence their restorative experience in the environment[59]. 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.

表4：与实验路段街道环境疗愈性显著相关的街景元素（n=25）
Table 4: The streetscape elements with significant correlation to the restorativeness of the selected section (n = 25)

	地形起伏 Slight height variations	绿植 Greenery	自行车 Bicycles	围栏 Fences	建筑 Buildings	墙体 Walls	骑行者 Cyclists	汽车 Cars
促进的疗愈性因子（正相关） Promoted sub-constructs (positive correlated)	B1 (0.013)	B1 (0.043)	—	—	—	—	B2 (0.032)	—
阻碍的疗愈性因子（负相关） Inhibited sub-constructs (negatively correlated)	—	—	E1 (0.003), E2 (0.000)	E1 (0.004), E2 (0.011)	F1 (0.018), F2 (0.016), F4 (0.020), E3 (0.038)	C2 (0.038), C3 (0.011)	E3 (0.017)	F1 (0.040)

注
p=0.05；括号内数字为相关性分析显著性值。

NOTE
p = 0.05; the given figures in the brackets are the significance values of sub-constructs.

5 结论与讨论

街道环境的疗愈潜力近年来已逐渐受到业界学者的关注[29][33]，但对疗愈性元素的系统性研究一直较为缺乏。考虑到当前高密度城市发展语境中人们对于日常疗愈环境的迫切需求，本研究探索了城市街道这一日常空间的疗愈性，并通过定性与定量结合的方式建立了抽象的疗愈性感知与具象的街道元素之间的联系，为以提升街景疗愈性为目的的设计提供了思路。

研究结果发现，“绿植”是人们在进行疗愈性评价时关注最多的街景元素，表明“绿植”对于街道环境的疗愈性具有重要贡献，这一点与已有研究[8]~[11]所证明的绿色自然元素的显著疗愈功能相一致。进一步的分析表明，不同街景元素对ART中4个特征因子影响的重要程度及机制不尽相同。例如，“绿植”对远离性、迷人性和延展性三个因子的核心影响、“人”对兼容性的重要影响，以及“汽车”的影响在延展性因子评价中的增强等都揭示了规划设计能够介入的环节和手段，也为制定针对性的疗愈性街景设计提供了实证依据。

然而，因目前聚焦于街道环境的研究较少，且“问卷调查＋眼动追踪”的方法仅能识别出街道的内容元素，无法识别其特征属性（如

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,

复杂度、开阔度等[33][61][62]），导致除“绿植”“人”“汽车”外，未能在已有研究中发现有关其他9类街景元素的类似结论。因此，应在未来的研究中进一步探索建立既包含内容元素又涵盖特征属性的街景疗愈性评估框架。未来研究亦可采用除RCS以外的基于其他理论基础的量表，以丰富街景疗愈性的内涵。同时，鉴于“问卷调查＋眼动追踪”的混合研究方法能在主观感知和客观环境之间构建联系，也可灵活运用于其他环境心理学研究。

另一方面，本研究在方法和技术上仍存在不足之处，有待在后续研究中改进。研究选取路段为通勤类街道，两侧界面的功能、形式均质单一，元素构成较为简单；由于被试者的疗愈感知会随着街道功能（如商业街、景观街等）和特征的变化而变化，因此研究使用的疗愈性量表中4个特征因子影响疗愈性体验的重要程度也会相应发生变化；未来还需针对其他不同类型的街道展开相关研究，以针对性地总结出提升各类街道疗愈潜能的方法。此外，研究发现街景元素在视频图像中的占比与其注视频次占比之间具有显著相关性（p=0.05），表明某一元素的注视频次占比较高可能是由于其在视野中占比较大。在以后的研究中应继续改进实验方法，尽量消除这一影响，进一步提高高频注视点与疗愈性街景元素之间关系识别的准确性。

综上，本研究强调在城市生活的日常环境中获得疗愈体验的重要性，并探究了街道环境具备的疗愈性。通过发掘不同街景元素对疗愈体验的促进或遏制作用，建立街景元素与疗愈性之间确切的对应关系，可有效服务于差异化街道的疗愈性提升改善实践，帮助专业人员依据不同类型街道的疗愈性侧重点制定相应的设计改善思路。研究结果表明，街道环境本身具有较多待挖掘的社会价值，城市环境中也存在许多能够媲美自然环境的疗愈性场所，值得进一步探索。**LAF**

and the failure of the “questionnaire-and-eye-tracking survey” method in describing the qualitative attributes of streetscapes (e.g. complexity, openness[33][61][62]). 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**

注释

本文部分内容基于第一作者殷雨婷在谢菲尔德大学的博士论文研究课题“探索城市街道疗愈性设计途径——以上海市为例”写作。

NOTE

This paper is partly based on Yin Yuting, the first author’s doctoral dissertation “Towards Delivering Restorative Street Design Principles in Shanghai, China” at The University of Sheffield.

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