Review

A Review of Attention Restoration Theory: Implications for Designing Restorative Environments

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A Review of Attention Restoration Theory: Implications for Designing Restorative Environments

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Abstract: The promotion and development of healthy cities are vital for enhancing human habitats and fostering sustainable economic growth. Based on the core database of Web of Science and the knowledge graph software, this paper makes a quantitative analysis of the literature related to attention recovery abroad. It is found that in recent years, the research on attention recovery has developed rapidly, the number of related literature has been increasing, and the research content presents the characteristics of interdisciplinary integration. By further analyzing the characteristics of research literature, research context, and knowledge basis, this paper summarizes the empirical research based on the existing quantitative analysis, reviews the research field based on the mechanism of attention recovery, and analyzes the development process and trend based on the research basis of attention recovery. Due to the change of modern life style, human health problems are becoming more and more prominent. Attention restoration design provides a new research idea and method to balance the relationship between humans and the urban environment.

Keywords: attention recovery; pressure recovery; healthy; quantitative analysis

1. Introduction

The information age has ushered in intensified social competition. Modern lifestyles have undergone significant changes, resulting in various public health issues. Compact urban environments and the stressful modern urban lifestyle are significant contributors to mental and chronic illnesses. Consequently, the promotion and development of healthy cities are vital for enhancing human habitats and fostering sustainable economic growth. To attain the objective of a health-focused built environment, the worldwide construction industry has prioritized the integration of health concepts into spatial design. The United States has developed the "WELL Healthy Building" evaluation standard, specifically designed to assess the mental and physical health implications of the built environment. To proactively and effectively tackle current prevalent health issues, China has formulated and issued documents related to the Healthy China Action(Wang, 2020). The emergence of concepts such as "healthy city", "healthy community" and "healthy building", ushered the health concept into the realm of architectural environmental design. Spatial environment design places greater emphasis on enhancing the comfort and enjoyment of the spatial experience.

Scholars have demonstrated that the environment can indeed influence the mental health and attention levels of residents(Ulrich, 1991). Prolonged residence in a low-quality environment not only results in various physical and mental health issues but also leads to reduced work efficiency, enthusiasm, and other adverse effects. Since the 1980s, numerous studies have demonstrated that natural environments can restore attention and alleviate stress(Yin, 2019). The information overload and stressful urban environments in modern cities expedite the depletion of individuals' attention resources. Anticipate a rising demand for rejuvenating environments in the future. It is worth highlighting that substantial attention has been directed toward the concept of "attention recovery," which initially emerged within the realm of environmental psychology. In the last three decades, attention-related research has revolved around two primary theories: Stress Reduction Theory (SRT) and Attention Restorative Theory (ART). Roger Ulrich introduced the Stress Reduction Theory (SRT)

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in 1979(Kaplan, 1989), while Stephen Kaplan introduced the Attention Recovery Theory (ART) in 1983(Kaplan, 1995). Table 1 displays the evolution of pertinent attention recovery theories. Stress Reduction Theory (SRT) centers on immediate and unconscious emotional reactions induced by the environment(Korpela,2002). Attention Recovery Theory (ART) concentrates on cognitive responses and posits that exposure to nature can facilitate the restoration of depleted directed attention resources, alleviating cognitive fatigue. Stress Reduction Theory and Attention Recovery Theory are not mutually exclusive, both share a common foundation in biophilic concepts(Kaplan, 1995).

Table 1. Development process of relevant theories of attention recovery.

Theory			Author	Time	Content
Theories related to attention recovery	Stress Reduction Theory (SRT)		Roger Ulrich	1979	When an individual is in a state of stress or stress, exposure to some natural environment can alleviate the physical, psychological, and behavioral damage caused by the stressor.
	Attention Restorative Theory (ART)	Autonomous attention and involuntary attention concepts	William James	1892	William James developed the concept of voluntary attention and involuntary attention. When the object itself is not attractive but has to pay attention to it, people mobilize autonomous attention, and vice versa.
		Concept of directed attention	Messalam	1985	Directed Attention, which is similar to Directed attention, is considered important for human health in modern neuro medicine.
		Put forward the theory and the characteristics of the recovery environment	Stephen Kaplan	1983	To refine the theoretical framework and fascination, the Kaplans added three other features of the restorative environment -- being away, extent, and compatibility.
		Psychological perspectives and natural experience	Stephen Kaplan	1989	The environment restores directed attention by providing certain qualities and provides individuals with opportunities for contemplation. This process is called a restorative experience. Accordingly, such an environment is a restorative environment.
		Integration of the natural recovery benefit framework	Stephen Kaplan	1995	Strong and continuous use of directed attention will lead to the consumption of this resource, making individuals frequent errors and impulsive behavior, but in a restorative environment, individuals can effectively recover attention.

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Over the past decade, an increasing number of studies have emerged from various fields, including environmental psychology, health psychology, and sports psychology(Berto,2014). Analyzing spatial quality through the lens of attention restoration design is beneficial for advancing research. Investigating human psychology and behavior allows researchers to comprehend how enhancing the built environment can contribute to the enhancement of human health.ch on environments that enhance human cognitive function and attention restoration capabilities. The fundamental attributes of a restorative environment serve as a theoretical foundation for crafting artificial environments conducive to restoration. This approach aids in dissecting the positive and negative elements of the surroundings, thereby unveiling the abstract environmental quality. These abstract attributes provide designers with a more diverse range of methods for implementing attention restoration theories, beyond merely incorporating greenery into interior spaces.

This study seeks to enhance the connection between individuals and the urban environment, addressing the growing health concerns through an analysis of attention restoration research processes and trends. Using the core database of Web of Science and the knowledge graph software such as Citespace, the paper conducts a quantitative analysis of pertinent foreign literature. The research indicates that attention restoration studies have garnered significant interest from scholars globally. Nevertheless, numerous studies on attention restoration have yet to be translated into practical applications, presenting ongoing challenges that require further investigation and resolution.

2. Methodology

2.1. Data Collection

The Web of Science database is recognized for its comprehensive coverage of academic literature spanning various disciplines, providing researchers with access to a diverse range of attention recovery studies across different fields. This ensures a thorough representation of the current literature. Knowledge graph facilitates quantitative analysis by visually representing relationships and connections among studies. Its visualization capabilities track trends and the evolution of attention recovery research, providing a longitudinal perspective that ensures retrospectives capture not only the current state of the field but also its historical development., including co-occurrence of research disciplines, publication trends, and publication sources, keywords and their evolution trends, main authors and high-frequency cited literature, etc. Then, the literature analysis function is used to sort out the research context and knowledge basis in this field. The key nodes and hot trends of attention recovery design are explored by using a knowledge graph. Based on the analysis of the cite space's knowledge graph and the sorting of key knowledge contexts, the empirical research, research field, development process, and trend of attention recovery are sorted out and summarized.

2.2. Research Framework

The basic data of this paper comes from the Web of Science core collection database. By comparing the results several times and by trial and error, the Topic = (" restorative environment "OR" stress recovery "OR" attention recovery "OR" perceived recovery")AND (environment OR architecture OR building OR urban). As a result, 5841 foreign articles were screened, and the obtained literature was screened for intensive reading: ① Papers of literature type selection, conference proceedings and review papers ② Citation frequency is higher or citation centrality is higher than 0.1. Some literature with weak correlation was removed, and 571 kinds of literature were screened out for analysis. Based on this, the mechanism of attention recovery theory and research development trend involved in the selected literature were analyzed in the next step. The analysis and retrieval tool of the Web of Science database, the knowledge graph software, and 571 literature records were analyzed. The research conceptual model is shown in Figure 1.

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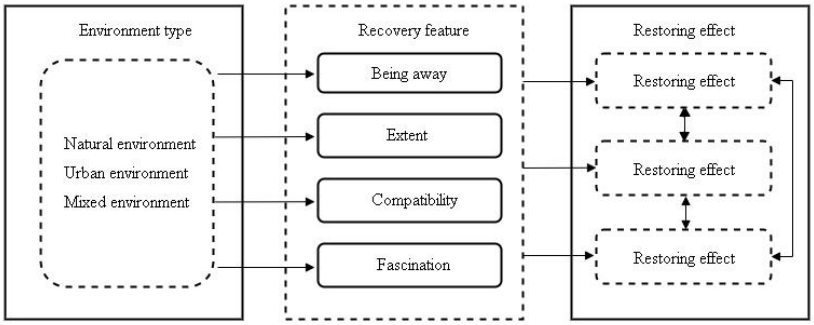

Figure 1. Study the conceptual model.

3. Results

3.1. Quantitative Analysis

3.1.1. Research Subject Co-Occurrence Analysis

Statistics show that attention recovery theory covers a wide range of research directions in the Web of Science database. The main disciplines are "Environmental Sciences", "Environmental Studies", "Ecology", "Social Science" and "Psychology". These have been major areas of attention recovery research for the last decade, And these research directions have gradually expanded to such disciplines as Public Administration, Urban Studies, Engineering, Computer Science, Business, and so on. Various research fields are integrated, and there is a strong correlation among research disciplines (Figure 2).

Figure 2. Co-occurrence analysis of research disciplines.

3.1.2. Analysis of Publication Trends and Publication Sources

According to the statistical analysis of 5841 literature searched in the Web of Science database and 571 literature screened and processed in the year of publication, it can be found that the number of relevant literature has shown an increasing trend in the past ten years (Table 2), means that the

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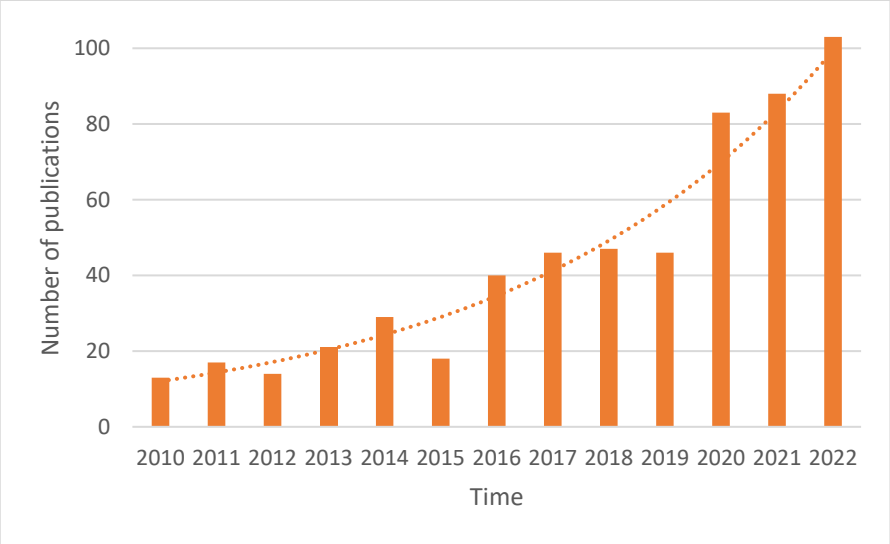
concept of health is receiving increasing attention nowadays. The design of comfort and livability of the space environment is also paid more attention by the public.

Table 2. Trends of attention recovery studies published in the past decade.



Through the statistical analysis of literature sources with the tools of the Web of Science database, it is found that INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH published the most papers. FRONTIERS IN PSYCHOLOGY, URBAN FORESTRY URBAN GREENING, SUSTAINABILITY, JOURNAL OF ENVIRONMENTAL PSYCHOLOGY, and other journals followed. It can be seen that in recent years, public environmental health, psychology, urban green space, sustainability, and other relevant journals have paid more attention to the study of attention restoration design.

3.1.3. Keyword Atlas Analysis

Import 571 literature records into the knowledge graph software , and run the software as a "keyword" node, corresponding to Descriptors and Identifiers in Web of Science database records. The threshold was set to 20, Timespan was set to 2010-2022, and the Time slice was set to 1. The time slice selected the top 50 literature of each time slice, and finally got the node N=186, among which the topics that appeared more than 100 times were: benefit, Environment, stress, Exposure, preference, and Health. Finally, the line E= 1061 is obtained, indicating that there are more cross-studies among various topics and a strong correlation. With the gradual deepening of the research, the main keywords with high frequency gradually expanded to other related topics. Examples include "environmental psychology", "biophilic design", "directed attention", "nature exposure" and "health benefits" Keywords such as "benefit", "perceived restorative" and "stress reduction theory" will continue to be the focus of research in 2019-2022 (Figure 3). Subject words with node N > 20 are selected and classified and summarized from the three directions of effect subject, effect object and effect mechanism (Table 3). Among them, nodes with centrality greater than 0.1 are called key nodes. There are four key nodes: Attention, Response, Environment, and Landscape. In summary, the research showcases the evolution of the literature and research trends in the specified field, highlighting key topics, their interconnections, and the depth of investigation. It also suggests a continuous focus on certain core keywords alongside the emergence of new and related topics.

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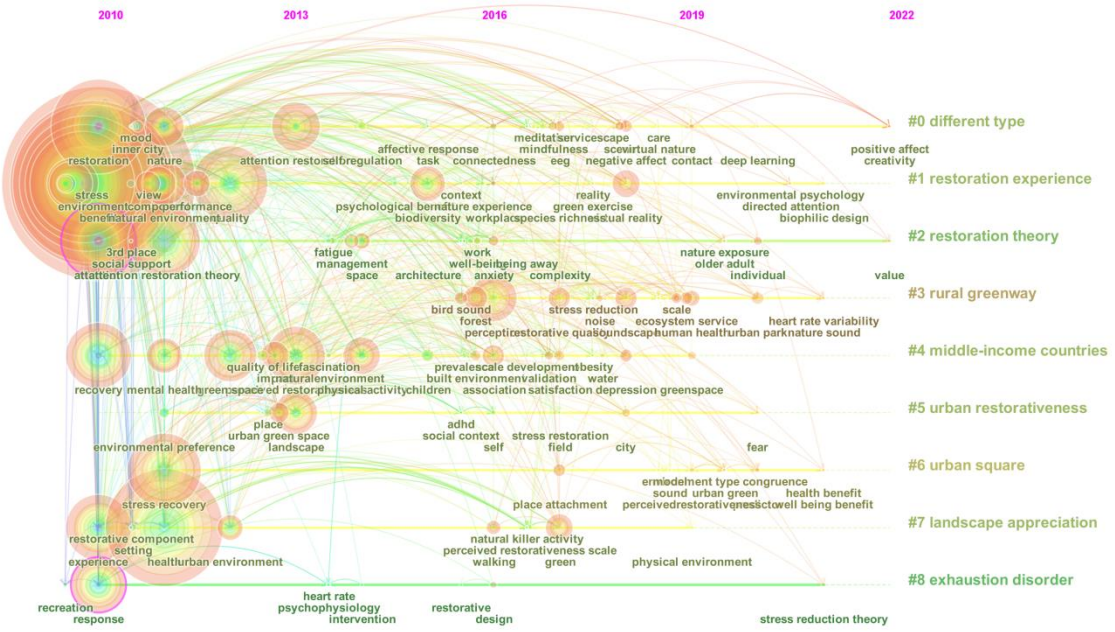

Figure 3. Timeline of keyword and cluster analysis.

Table 3. Clustering analysis of keywords in attention recovery based on node N > 20 in cite space computing network.

Effect Object			Effector			Effect Mechanism		
Subject Word	**Total**	**Centrality**	**Subject Word**	**Total**	**Centrality**	**Subject Word**	**Total**	**Centrality**
Stress	142	0.03	Environment	149	0.1	Benefit	174	0.09
Preference	108	0.08	Restorative Environment	99	0.06	Exposure	121	0.09
Health	106	0.08	Green Space	48	0.09	Restoration	90	0.06
Attention	74	0.17	Urban	44	0.02	Stress Recovery	69	0.07
Response	54	0.12	Natural Environment	42	0.05	Experience	60	0.08
Perception	42	0.05	Landscape	42	0.1	Perceived Restorativeness	56	0.06
Mental Health	37	0.02	Biodiversity	36	0.06	Psychological Restoration	53	0.03

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Performance	24	0.04	Virtual Reality	28	0.01	Attention Restoration	45	0.03
Human Health	15	0.01	Forest	26	0.02	Impact	28	0.03
Anxiety	12	0.04	Space	21	0.04	Association	22	0.01

3.1.4. Knowledge Base Analysis

Applying the Web of Science database, this research systematically selected and integrated literature based on relevance and citation frequency. Subsequently, this research compiled a list of ten highly-cited papers in the field of attention recovery from international sources, each cited more than 100 times in the past decade. These papers serve as crucial theoretical references for studies related to attention recovery (Table 4). Markevych (2017) and Bratman (2012) (2019) have comprehensively examined the influence of natural experiences on human cognitive function and mental health. They achieved this by incorporating insights from environmental psychology, urban planning, health science, social science, landscape aesthetics, and related fields. Tyrvainen (2014), Berman (2012), Carrus (2015), Ratcliffe (2013), and Van den Berg (2014) have collectively adopted an experimental approach to validate the benefits of natural environments. These studies have independently confirmed the positive impacts of short-term visits to natural urban areas on stress reduction, the advantages of nature walks for patients with major depressive disorder (MDD) the favorable effects of biodiversity on urban green spaces and their perceived restorative qualities , the potential of sound in aiding attention and stress recovery and the restorative effects of varying levels of natural elements in urban public spaces. Keniger (2013) and Ohly (2016) systematically summarized the attributes of restorative natural environments and the methodologies and empirical evidence used in attention recovery research . They focused on research methods and theories. We analyzed the authors of the selected literature and identified five influential figures in attention recovery research over the past decade. These authors are Hartig Terry, Korpela Kalevi, Grahn Patrik, Berman Marc G and Tyrvainen Liisa. Analyzing recent literature and findings from relevant authors in the past decade reveals a consistent focus on specific types of natural environments. The balance between artificial intervention in natural environments and entirely wild environments is approximately 1:1.Nevertheless, there is limited research on urban environments. Exposure durations for environmental testing vary significantly, typically spanning from 1 minute to 4 hours with 10-15 minutes being the most prevalent duration. Stress reduction theory proposes that exposure to certain natural environments can mitigate the physical, psychological, and behavioral effects of stressors. However, the majority of articles do not incorporate stressors in their studies. In the limited studies that incorporated stressors, these stressors encompassed cognitive tests conducted by Brown (2013) and Hartig (2003), mild electric shocks administered by Hedblom et al. (2019) , arithmetic tests employed by Valtchanov and Ellard (2010) and the organization of stressful film clip viewings by Park et al. (2020). Notably, Sonntag et al. (2014) did not introduce stressors but instead focused on subjects from high-stress groups.

Table 4. Hot foreign literature on attention recovery in the past decade.

Author	Publication Time	Cited Frequency	Article Title	Research Content
Markevych	2017	866	Exploring pathways linking greenspace to health: Theoretical and methodological guidance	The paper explores the interdisciplinary evidence linking green spaces to health.
Keniger, LE	2013	556	What are the Benefits of Interacting with Nature?	The study constructs new typologies of human-nature experiences and employs them to

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				assess the benefits of human-nature interaction.
Bratman, GN	2012	526	The impacts of nature's experience on human cognitive function and mental health	The synthesis of multiple disciplines outlines how exposure to nature and an individual's preference for nature may influence the impact of the environment on mental functioning.
Tyrvainen, L	2014	499	The influence of urban green environments on stress relief measures: A field experiment	The paper experimentally investigated the psychological and physiological effects of short-term visits to urban natural environments.
Bratman, GN	2019	461	Nature and mental health: An ecosystem service perspective	The paper extends the assessment of ecosystem services to mental health and proposes a heuristic conceptual model for this purpose.
Berman, MG	2012	389	Interacting with nature improves cognition and affects individuals with depression	The study experimentally investigated the benefits of nature walks in patients with major depressive disorder (MDD).
Carrus, G	2015	387	Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting, urban and peri-urban green areas	Field studies assessed the benefits and subjective well-being of urban residents accessing four different types of green space.
Ohly, H	2016	260	Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments	The study experimentally explores the mechanism of environmental restorative experience.
Ratcliffe, E	2013	204	Bird sounds and their contributions to perceived attention restoration and stress recovery	The study found a relationship between bird calls, the most common type of sound in nature, and attention recovery.
Van den Berg, AE	2014	193	Evaluating restoration in urban green spaces: Does setting type make a difference?	The study examines the storability of urban public spaces with varying degrees of greening. The results indicate that the restoration of urban public spaces depends on individuals' perceived needs and the physical characteristics of the environment.

The literature cited in these studies collectively underscores the profound influence of natural experiences on human mental health and cognitive function. These studies offer valuable interdisciplinary and experimental insights, emphasizing the restorative attributes of nature, the potential influence of sound, and the necessity to investigate natural environments with attention-

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restoring qualities. Furthermore, these studies stressed the significance of a robust theoretical framework and research methodologies in attention recovery research, furnishing a fundamental theoretical foundation and reference for future investigations. While current research is dispersed across various fields, including psychology, engineering, physiology, medicine, and environmental science. However, concentrating on the overarching theme of this emerging field, rather than delving into specific details, facilitates the integration of research content. Moreover, a balance between theoretical and empirical research should be achieved, but currently, there exists no model or framework to guide the development of measures or methods for creating restorative natural environments. Furthermore, it is crucial to strike a balance between theoretical and empirical research. However, currently, there is a lack of a comprehensive model or framework to guide developing measures or strategies for creating restorative natural environments.

3.2. Qualitative Analysis

3.2.1. Summary of Empirical Research Based on Quantitative Analysis

Through meta-analysis of existing research literature, it can be seen that most researchers have quantified individual psychological and physiological indicators with the help of empirical research methods, including observation method, conversation method, test method, experiment method, case method, etc. Experimental sites are divided into laboratory and field. The test groups include college students, high school students, children, ordinary adults, patients, etc. The content of the test includes people's psychological reactions, physiological reactions, and cognitive performance(Park, 2020).

Research Methods and Steps

Experimental methods are commonly employed in attention recovery studies because they allow researchers to control for unrelated variables in a specific environment. This control is essential for investigating the intricate mental processes involved in attention recovery. Researchers frequently utilize experimental methods to intentionally expose subjects to specific stimuli in a highly controlled environment, eliciting psychological and physiological responses. Following the presentation of the stimulus, researchers analyze the subjects' responses through direct observation, face-to-face conversations, and comprehensive questionnaire tests. Previous studies predominantly employed experimental methods in laboratory settings, conducting randomized controlled experiments to generate empirical data for attention recovery research. Experimental stimuli encompassed sound, analog images, and videos. Emfield and Neider conducted a study in which participants completed a battery of stress tests. Subsequently, participants were exposed to images of a designated environment as part of a restorative experiment. Finally, cognitive tests were administered to assess the recovery effects. Some of these studies incorporated sound variables alongside visual stimuli(Emfield,2014). Evensen et al. investigated the restorative effects of various environmental settings on subjects using window views(Evensen,2015). Some studies were conducted in real-world outdoor environments. For instance, in 2015, Bratman et al. investigated the attention-restoring effects of nature by observing how subjects interacted with natural settings, such as walking or jogging in natural surroundings (Bratman,2015). Some studies also employ a case study approach, aiming to investigate and comprehend the long-term psychological changes in the test group. For instance, in 2015, Pilotti et al. conducted a video-based study on the environmental restorative effects of the test subjects. They also carried out a prolonged follow-up to enhance experimental accuracy(Pilotti,2015).In the current era of rapid technological development, virtual natural environments emerge as a potential solution. The experimental conditions and scenarios in virtual environments have become crucial for studying attention recovery in recent years. Researchers can precisely manipulate variables as needed, making it suitable for investigating attention recovery in various fields, including urban planning, medical facilities, and educational environments.

The experimental method plays a crucial role in attention recovery research as it helps in comprehending the mechanisms behind attention recovery and the impacts of environmental

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restoration. It offers a controlled environment for configuring specific stimulus factors and gathering data. As a viable alternative, virtual natural environments present a novel approach to investigating attention recovery, significantly enhancing and expanding the knowledge base in this domain. Nonetheless, researchers must remain vigilant about potential health issues among subjects immersed in virtual environments during the research process.

Classification of Environment Types

Various studies encompass different environmental types, which can be broadly categorized into three groups: natural environments, urban environments, and mixed environments. In the realm of psychological research, these distinct environmental types exhibit varying impacts on attention recovery. The majority of studies delve into these three main environmental categories to investigate their differential roles in regulating attention recovery. Research consistently indicates that natural environments are generally deemed more restorative, and contact with such environments is beneficial for human health and well-being. Beyond the direct influence of environmental quality, the natural environment contributes positively, primarily by enhancing stress and emotional regulation (Browning, 2020). Being in nature also yields favorable effects on physiological responses, including blood pressure, heart rate, skin conductivity, muscle tone, and cortisol levels (Horiuchi,2013). Additionally, a multitude of studies have demonstrated that landscapes incorporating natural elements as stimuli are more restorative compared to those featuring artificial elements (Park,2010). Consequently, many scholars employ natural environments as exemplars of restorative settings in their research. For instance, Beute (2014) examined the impact of nature on attention recovery through empirical research, while Bowler (2010) and Bratman (2015) investigated the positive effects of green spaces on mood enhancement and cognitive function improvement.

Urban environments, characterized by busy streets, crowded spaces, and tall buildings, often harbor potential stress-inducing factors when compared to natural surroundings. While urban environments may not offer the same level of restoration as natural settings, they do provide unique aesthetic experiences that can capture a portion of one's attention. Some researchers have even discovered that attention can be captivated by artificial objects that exhibit visual properties resembling those found in nature. Substituting a natural object with an artificial one possessing similar properties (e.g., color, shape, sound, etc.) can produce a comparable restorative effect (Ohly,2016). Thus, creating a restorative built environment entails incorporating elements with natural qualities. These natural qualities in a space are not merely achieved through nature simulation but can also involve providing analogous properties (such as structural complexity and cohesion) abstractly to simulate nature, thereby promoting stress relief. Understanding these principles is paramount in designing restorative urban environments. In recent years, an increasing number of scholars have shifted their research focus from natural environments to urban settings. For instance, Lyu (2022) examined the spatial characteristics within workplaces conducive to enhancing employee work efficiency and mental health. Jeon (2021) explored the potential restorative effects of urban soundscapes. Furthermore, Sonntag et al. (2014) conducted experimental research investigating the disparities in the impact of urban and natural environments on visitors' attention levels and physiological responses.

A hybrid environment combines elements of both natural and urban settings, such as a city park or a view that blends both aspects. Research indicates that such mixed environments also exhibit a degree of restorative potential, attributed to the diverse composition of these spaces, which enhances their visual appeal. This heightened attraction contributes to memorable and pleasurable experiences, fostering creativity and cognitive abilities. The richness of content within mixed environments can elevate individuals' sense of pride and belonging, consequently reducing stress levels and improving mood. For instance, studies conducted by Sllivian (2016) and Evensen (2015) explored the restoration effects of window views within mixed environments. These investigations offer valuable insights into the incorporation of natural elements into urban landscapes to enhance human well-being.

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In addition to studying natural, urban, and mixed environments, this research also delves into the specific restorative qualities of landscapes. Various elements, including materials, shapes, colors, and textures within the environment, can exert distinct effects on attention recovery (Stevenson,2018). By selecting materials that align with people's emotional expectations, it becomes possible to establish a relaxed and comfortable ambiance. A skillful combination of soft and hard materials, as well as artificial and natural elements, can create a well-balanced and harmonious spatial experience, thereby enhancing user satisfaction. Soft materials, such as plush fabrics and natural fibers, impart a sense of comfort and contribute to a tranquil and inviting atmosphere. The tactile quality of these soft materials can also have a soothing effect, aiding in tension relief. Hard materials like metal, glass, and plastic readily establish a sense of structure and order, conveying feelings of stability and firmness to provide users with a heightened sense of security. Conversely, natural materials such as wood, bamboo, and natural stone have an innate connection with the natural world. The incorporation of these natural materials serves to strengthen the bond between individuals and nature, contributing to the reduction of daily stress.

Research into attention-restorative environments encompasses various dimensions. While natural environments are generally accepted to have superior restorative effects, the distinctive attributes of urban and mixed environments, along with their diverse elements, offer a unique perspective for attention restoration design. This is instrumental in advancing the continued growth of this research domain.

Evolution of Measurement Methods

The most common tool for assessing the restorative potential of the environment is the Perceptual Recovery Scale or its variants. The restorative impact of the environment on an individual can be gauged using psychological questionnaire scales. Hartig and Korpela, among others, initially developed the Perceptual Recovery Scale, which was subsequently modified by Herzog and Colleen. Each scale required participants to assess various dimensions based on their emotional responses to the environment. In their 2014 study, Van den Berg and Jorgensen utilized the self-rated Restorative Scale (RS), while Laumann in 2001 and Stevens in 2014 employed the Restorative Component Scale (RCS) . The development and research details of the Perceptual Recovery Scale are presented in Table 5.

Table 5. Development and research contents of perceptual recovery scale.

Theory	Author	Time	Content
PRICE	Hartig	1997	To measure the restorative nature of human-environment interaction, Hartig et al. developed the Perceptual Recovery Scale (PRS) to measure the quality of the restorative environment.
RCS	Laumann	2001	To make up for the shortcomings of PRS, Laumann et al. developed another set of environmental recovery component rating scales, which was named as Recovery Component Scale (RCS) in subsequent studies.
RS	Han K T.	2003	Han K T et al. developed a reliable and effective self-assessment method for the quality of natural environment restoration, called the self-assessment Restoration Scale (RS).
PRCQ	Pals	2009	Pals et al. believe that zoos have restorative features in addition to natural environments. Based on PRS and RCS, they designed the Perceptual restorative Feature Scale (PRCQ) for five kinds of restorative features of zoo attractions.

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PDRQ	Lehto	2013	From the perspective of tourists, based on the theory of attention recovery, a 30-item PDRQ was developed.

Due to the subjectivity of psychological questionnaire scales, researchers have increasingly explored objective assessments of physiological indicators related to attention fatigue and recovery. Biologists have identified two divisions within the human autonomic nervous system (ANS): the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). Stress induces various changes in the human autonomic nervous system. Specifically, stress leads to an increase in sympathetic nervous system (SNS) activity and a decrease in parasympathetic nervous system (PNS) activity. Wearable physiological monitoring systems offer advantages over subjective reports, as they can overcome the limitations associated with subjectivity. Research outcomes frequently involve measuring physiological signals and stress-related indicators such as EEG, EMG, EDA, HR (heart rate), RR (respiratory rate), HRV (heart rate variability), and BPR (blood pressure), among others. The most frequently used measures include heart rate (HR) and blood pressure (BPR). Additionally, Kang et al. (2022) and Park et al. (2007) assessed cerebral blood flow. Zeng et al. (2020) assessed oxygen concentrations before and after the experiment. Kobayashi (2019) and Yu et al. (2018) evaluated salivary alpha-amylase levels. Genole et al. (2016) assessed salivary testosterone levels . Li et al. (2011) determined the concentrations of adrenaline and dopamine in urine. Hassan et al. (2018) and Reeves et al. (2019) recorded EEG measurements in their studies. Despite substantial variability in the measured variables, no significant differences were observed in the results. Blood pressure was the most frequently employed measure in this study, with approximately half of the previous literature utilizing it. Nevertheless, blood pressure has demonstrated low sensitivity, and a substantial body of research suggests that heart rate (HR), heart rate variability (HRV), and salivary cortisol are more appropriate for measuring physiological indicators in this context(Corazon,2019; Kondo,2018).

3.2.2. Analysis of Research Fields Based on Action Mechanism

The process of attention recovery can be defined as a multi-stage experience process, which starts with attention recovery to reduce negative emotions and increase a series of positive emotions (Arnett,2016). The information provided by the environment can be divided into different types of stimuli according to people's feelings. Stimuli are defined as factors that can affect human organic activities (Sedghikhanshir,2022). Individuals can perceive the stimuli of the surrounding environment through basic perception such as vision, hearing, touch, and smell, and produce a series of physiological, psychological, and cognitive reactions (Pinto,2013). The mechanism model is shown in Figure 4. Previous research fields mainly focus on psychological recovery, physiological recovery, and cognitive recovery (Ohly,2016; Menardo,2021).

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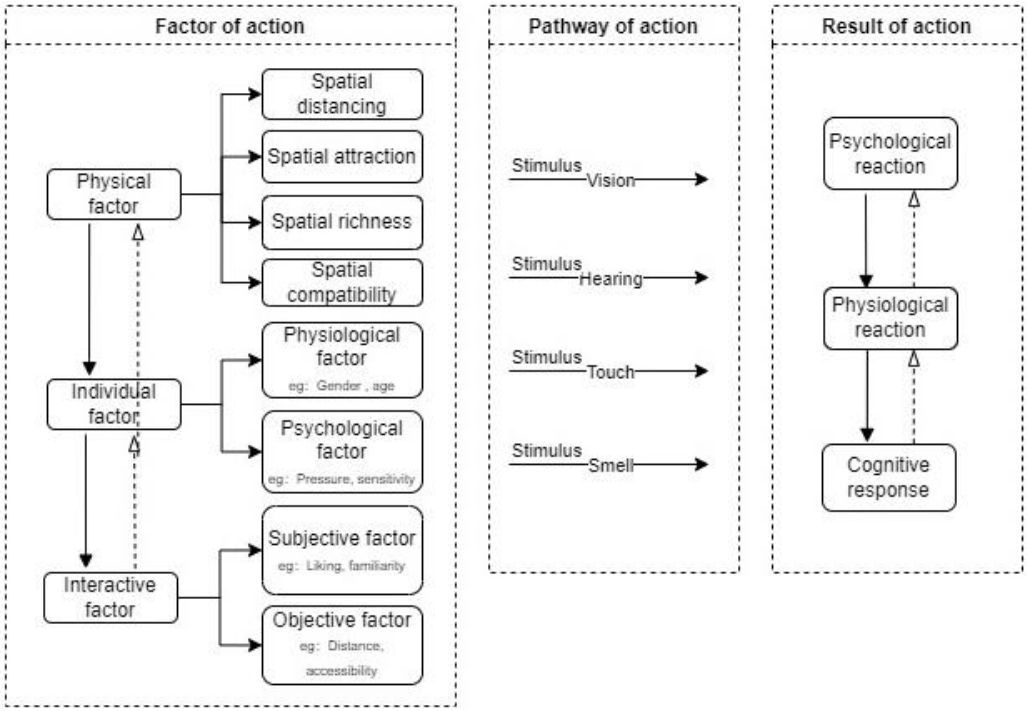

Figure 4. Mechanism model of attention recovery.

Subjective Exploration of the Psychological Level

The keywords in psychological recovery research encompass terms such as "Stress," "Preference," "Restoration," "Psychological," and "Mental," among others. Typically, this research relies on psychological questionnaires to subjectively assess the psychological responses of participants. Psychological recovery studies have commonly explored both directed and undirected attention(Folk,1992). Directed attention involves the intentional allocation of brain resources toward objects or areas linked to specific goals and tasks. Conversely, undirected attention is a cognitive resource that is spontaneously drawn toward salient stimuli without conscious control (Sedghikhanshir,2022). This study examines both attention consumption and recovery mechanisms, investigating how replenishing attention resources impacts psychological recovery. Research has demonstrated that prolonged directed attention can result in mental fatigue and, in severe cases, lead to significant mental health issues(Berto,2014). The restoration of attention resources leads to a reduction in negative emotions, providing individuals with a renewed sense of security and happiness. The restoration of attention resources can alleviate feelings of burnout, boredom, frustration, and anxiety, leading to positive changes that can benefit mental health (Fandetti,2022).In situations where individuals experience negative emotions due to stress, the environment can aid in reestablishing their focus and improving their mood, resembling a form of psychotherapy. For instance, intriguing and innovative spatial designs can offer individuals a sufficiently enriching spatial experience, allowing them a temporary respite from negative emotions. When the environmental conditions offer individuals a sufficient sense of security and comfort, their psychological state can relieve pressure through sensory healing and transition into the recovery stage.

Objective Exploration on the Physiological Level

The key terms in physiological recovery research include "Health", "Exposure", "Experience" and "Association." This research typically builds upon psychological recovery and delves deeper into identifying physiological indicators for the objective assessment of attention fatigue and recovery. For instance, neuroimaging techniques like functional magnetic resonance imaging (fMRI) and

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electroencephalography (EEG) are employed to monitor changes in cortical activation during attention recovery and to measure hormone concentrations, such as adrenaline, serotonin, and dopamine, that play roles in regulating attention recovery. Research indicates that attention restoration can reduce stress and fatigue, enhancing physical functioning (Schumann,2022). This process can lower stress hormones, including heart rate, pulse rate, blood pressure, salivary cortisol, and adrenaline, alleviating physical stress. Additionally, it aids in balancing metabolism, decreasing the likelihood of heart disease, cardiovascular and cerebrovascular diseases, and other stress-related conditions(Ryan,2014). Physiological and mental health are interconnected, influencing each other significantly. Positive mental health boosts the immune system, motivating physical activity and enhancing overall well-being(Timm,2018). Simultaneously, maintaining physical health is crucial for mental well-being.

Validation Research on a Cognitive Level

Key terms in cognitive recovery research include "Attention", "Response", "Performance", and "Perception".Cognitive recovery is the most direct outcome of replenished attention resources. Researchers frequently assess task performance both before and after attention recovery. They also engage in long-term tracking and observation of cognitive behavior. Studies have shown that the relationship between attention recovery and cognitive ability lies in its support for work efficiency and sustainability. If attention resources are not supplemented in time, people may experience memory decline, slow down reaction speed increase error rate, etc., thus leading to a negative attitude towards cognitive tasks(Stevenson,2019). On the contrary, timely replenishment of attention resources can keep people's cognitive ability at an optimal level, and regular attention recovery is conducive to promoting sustainable utilization of cognitive resources, which is crucial for long-term and sustainable work(Korpela,2015). The recovery of attention also has a series of positive knock-on effects, such as the ability to complete work tasks by providing continuous resources of attention, which in turn increases self-confidence and self-identity, and finally increases enthusiasm and motivation for work. In addition, innovation is a key skill in the knowledge age, and the process of innovation often requires a high degree of concentration. Abundant resources of directed attention are essential for those who engage in mental work for a long time(Korpela,2015).

3.2.3. Development Process and Trend Analysis Based on Research

Review the Development Process of Attention Recovery Research

Through a comprehensive review of existing research literature and content, it is evident that the research process can be divided into three distinct stages (Figure 5):

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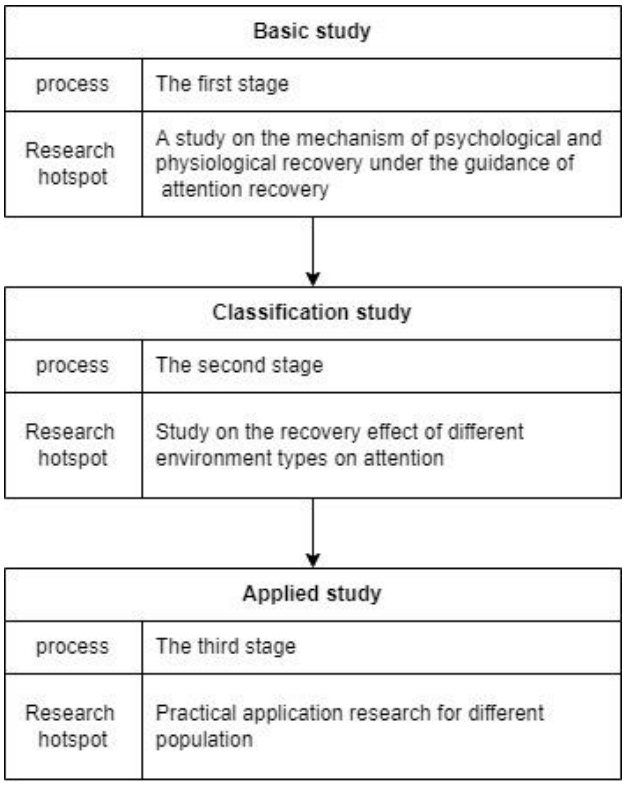

Figure 5. Research process diagram.

(1)First Stage: Investigating Psychological and Physiological Recovery Mechanisms Guided by Attention Recovery

In the initial research phase, scientists concentrated on the psychological and physiological mechanisms of attention recovery, crucial for comprehending the consumption and replenishment of attention resources. In this research phase, significant background and theoretical frameworks provide essential support. Kaplan's Attention Restoration Theory (1989) posits that exposure to natural environments promotes the recovery of directed attention, highlighting nature's role in replenishing attention resources and reducing mental fatigue. Baumeister et al.'s Resource Exhaustion Theory (1998) asserts that self-control and concentration utilize limited cognitive resources, emphasizing the importance of recognizing these limitations in studying attention recovery. Studies on neural mechanisms, including the utilization of techniques like functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) to monitor brain activity during attention recovery, have established a scientific foundation for this process (Park,2007). During this stage, theoretical and empirical studies related to attention recovery mechanisms are particularly active. For instance, Kaplan (1995) delved into the mechanism of directed attention and its influence on emotional and cognitive performance, supported by existing experiments. In 2013, Kirshbaum et al. conducted a study involving 25 patients experiencing moderate to severe fatigue. This research, grounded in attention recovery theory, employed non-pharmacological interventions aimed at alleviating the patients' illness-related discomfort. Ultimately, it offers valuable theoretical insights for the practical application of related research in clinical settings(Kirshbaum,2014).

(2) The Second Stage: Investigating the Impact of Various Environmental Types on Attention Recovery

As research advanced, the focus shifted toward understanding the environmental influence on attention recovery. Attention recovery theory continues to be pivotal in this research stage, underscoring the influence of environmental factors(Kaplan,1995). Research in environmental psychology exploring how diverse environments (urban, natural, and mixed) impact human behavior and cognition offers a theoretical foundation for understanding the influence of environmental traits on attention recovery (Beute,2014). Researchers like Mark Berman have

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extensively investigated the impact of urban environments and persistent stressors on attention fatigue, highlighting the significance of bolstering environmental resilience (Bratman,2012). At this stage, research predominantly centered on the interaction between various environmental types and attention restoration. For instance, Kaylin Adamson (2018) investigated the impact of different plant variables in office spaces on cognitive performance. In the 2018 experiment, Jason investigated the influence of natural elements and auditory stimuli on individuals' attention recovery. This exploration involved various sets of independent variables, such as combinations of natural photos with natural sounds, natural photos with classical music, and natural photos with classical music along with city scenes.

(3) The third stage: Practical Application in Different Contexts

In recent years, advancements in psychology, clinical medicine, and related disciplines have revealed that attention's restorative impact varies significantly across the human lifespan. Additionally, different social groups experience varying recovery intensities influenced by their unique factors. Distinct attention consumption patterns and recovery needs emerge among children, adolescents, adults, and the elderly due to physiological, cognitive, and experiential differences (Stevenson,2018). Practical research in fields like architecture, planning, and clinical psychology has increasingly focused on diverse groups, laying the theoretical groundwork for further attention recovery applications. This shift has led to attention to recovery studies exploring practical implications for different demographics. Notably, scholars such as Farhan Asim and Venu Shree integrated attention recovery theory with biological principles in 2019. Their work delved into the relationship between psychological recovery and nature, examining the influence and importance of various built environments in student dormitories on psychological recovery . Similarly, in 2012, Judith investigated design strategies aiming to enhance workplace happiness and attention levels, drawing from the biophile design theory and attention recovery concepts.

Overall, attention recovery research across the three stages mentioned has established a solid theoretical foundation, offering valuable guidance for advancing and refining relevant theories. However, existing research accumulation still presents certain gaps, limiting its applicability in design practices. Notably, restorative environment theory has predominantly focused on outdoor landscapes, with limited application in indoor environment design. Consequently, there's a pressing need for research on attention restoration in artificial settings. The ultimate aim of this field is to translate fundamental attention restoration research into practical architectural design applications. This approach can reshape research content patterns and drive the future development of human-centered building environments.

Trends in Attention Restoration Research

(1) Analysis method: From quantitative analysis to the combination of quantitative and qualitative analysis

In the early literature, research often integrated multiple disciplines such as environmental science, psychology, sociology, etc. Based on the relevant theories of attention recovery, this study sets up various experimental scenes or controls different research independent variables to further study the promoting effect of environmental types and environmental elements on human attention recovery. Then, evidence is carried out through psychological questionnaire surveys and other ways, aiming at quantitative analysis of subjective feelings(Jaggard,2014). However, in recent years, more research has been based on quantitative analysis. The research combines literature analysis, case analysis, participation experience, and other non-quantitative means and methods, discusses and studies the problem from a theoretical perspective, and finally puts forward countermeasures and suggestions. For example, Ming Lu explored the design strategy of a restorative campus based on students' perceived preferences in 2019 .

(2) Research subjects: the transition from the natural environment to the urban environment

In the early stage of research, scholars often regard the natural environment and the urban environment as two kinds of opposite environments. The main purpose is to investigate the advantages of the natural environment over the urban environment in promoting mental

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health(Yue,2022). As the study progressed, the researchers discovered how difficult it was to create an entirely natural environment in a highly urbanized area. Resilience is not only a special property of the natural environment but also a spatial property. Beautifully designed and attractive built environments have restoration benefits similar to those of natural environments. Therefore, the main research direction is to integrate the natural environment into planning and design with the artificial environment as the carrier, and finally create an acquired restorative environment (Ulrich,1991). Therefore, scholars began to explore the restorative space design of different building types, such as residential buildings, office buildings, schools, and hospitals, based on the previous theoretical basis. For example, Smith studied and discussed the design of an open office based on the attention recovery theory and biophile theory in 2013 . In The Green Office, Elzinga studied and discussed the effect of office plants on relieving mental fatigue and stress.

(3) Limiting factors: from the overall environment to a single environmental element

Most of the research is based on the influence of the overall natural environment or artificial environment on human physical and mental health because the early research is limited by the knowledge background. With further research, scholars began to study how individual environmental factors affect human psychological perception. These environmental elements include cultural background, visual arts, window views, space openness, interior landscape, color design, sound design, interior environmental quality, etc. For example, Myers studied the restorative effects of visual arts and place culture in 2020 . Evensen analyzed the influence of windowless landscape elements on computer workers in 2015 . Adamson explored the promoting effect of indoor landscape on individual cognitive performance in 2019 . In 2020, Amirbeiki studied the influence of exposure to natural blue elements on the psychological recovery of college students. Ratcliffe studied the restorative effect of sound production in 2021. Shengxian Kang studied the influence of indoor environment quality on the work efficiency of open scientific research office space in 2017.

4. Conclusions

In recent years, attention recovery research has gained significant attention from scholars globally, with a growing body of related studies year by year. The fundamental characteristics of restorative environments offer a theoretical foundation for creating artificial environments with restorative qualities. Applying attention restoration theory strategically can address issues related to excessive stress and low work efficiency in society. Numerous studies have highlighted the advantages of implementing attention recovery theories in architecture. However, a thorough analysis of the knowledge landscape reveals that many studies on attention recovery have not yet translated into practical applications, and certain challenges require further investigation and resolution:

(1) Most studies on attention restoration are rooted in changing social lifestyles and concepts across countries, the growing desire for vibrant architectural spaces, and the exploration of healthy building standards like WELL. While these theories have elucidated the potential of architectural spaces for attention recovery, there remains uncharted territory for integrating attention recovery research with architectural design and translating these theories into specific design strategies. The inherent subjectivity of attention recovery design strategies poses substantial challenges, influenced by personal perceptions, cultural variations, and diverse empirical backgrounds, further exacerbated by the absence of standardized guidelines for applying attention recovery theory in architectural practice. To address these issues, future research should adopt a more comprehensive approach, integrating attention recovery theory into a practical design framework.

(2) Most empirical studies on attention recovery are conducted in controlled laboratory settings, enabling researchers to explore intricate interactions between environmental factors and cognitive processes. However, some psychologists have pointed out a significant disparity between simulated environments and the real world in terms of sensory stimulation . This disparity can impact the assessment of environmental restorative effects. Environmental elements like natural light, ambient sounds, tactile sensations and olfactory cues recreated in a lab setting may not fully capture the richness and complexity of the real world. Consequently,

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cognitive responses triggered in artificial environments may differ substantially from those in real-world settings. As empirical research advances, addressing this discrepancy becomes crucial for enhancing the validity of research findings. Researchers must bridge the gap between laboratory simulations and natural ecosystems and refine research methodologies to identify factors influencing attention recovery.

(3) When selecting a sample population, it is common to prioritize young individuals, particularly college students, due to their distinctive cognitive characteristics. Nevertheless, one of the key sources of variability in psychological studies is the composition of the survey respondents , as diverse populations, age groups, cultural backgrounds, and life experiences can yield distinct cognitive responses. Overreliance on a single population, such as college students, heightens the risk of empirical bias and limits the generalizability of findings across various populations and environmental contexts. Given that the prevalent use of college students has raised concerns among researchers, future studies should opt for a diverse and representative sample. This includes individuals from different age brackets, occupational backgrounds, cultural contexts, and daily routines, to mitigate issues like experimental errors stemming from subject demographics.

(4) Currently, the majority of studies predominantly explore the visual aspects of environmental stimulation while overlooking the restorative potential offered by the environment through auditory, tactile, and olfactory stimuli. Expanding the scope of research to encompass multi-sensory stimulation can enrich individuals' spatial experiences. For instance, the gentle breeze or the rhythmic sound of flowing water in the auditory domain can evoke feelings of calm and relaxation. Tactile elements like unique textures or soft seating surfaces contribute to a sense of comfort. Moreover, natural fragrances or soothing scents in the olfactory realm can elicit positive emotional responses. Integrating diverse sensory dimensions fosters multifaceted restorative experiences and cognitive responses, thereby enhancing attention recovery.

(5) Lastly, the majority of prior studies have primarily focused on quantifying the impact of natural environments or natural elements on individual attention, physical well-being, and mental health, often overlooking investigations into urban environments. Despite the substantial body of evidence confirming the restorative attributes of natural elements, urban environments also possess significant restorative potential. While research on urban environments has seen a slight uptick in recent years, it remains relatively limited and fragmented, lacking in-depth exploration (Myers, 2022). Addressing this gap necessitates interdisciplinary collaboration among psychologists, architects, urban planners, and other stakeholders. This collaboration should aim to analyze how various urban elements influence cognitive recovery in individuals and advance the revitalization of urban environments in the context of contemporary society.

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