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Review

The Impact of Visual Stimuli and Properties on Restorative Effect and Human Stress: A Literature Review

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Abstract: Restorative environments are known as places where human stress can be decreased through restoration of depleted psychological resources. Since the efficiency of natural environments in restoration is supported by the literature, designing a restorative built environment can be obtained by integrating natural objects into built environments. However, various factors may lead to the failure of design intentions in real restorative environments such as visual stimuli and their properties. In addition, previous literature has widely used images and immersive virtual environments (IVEs) to deliver restorative environments in the design stage, and the impact of the delivery methods on visual properties needs to be considered. Therefore, the key to this study is to investigate the impact of visual stimuli and their properties on restoration along with the type of delivery method. To achieve this objective, the authors performed a literature review in two main steps. During the first step, the authors reviewed restoration and visual studies separately to understand the restoration and visual processes. Then, the second step of the review was conducted based on the results from the first step to review studies investigating the impact of different visual stimuli and properties on restoration. The literature review was conducted by combining scientometric analysis with a systematic review. In total, 1608 publications were retrieved from the Web of Science for scientometric analysis after applying search criteria. Then, the authors explored cluster reports generated by scientometric analysis to find publications for a systematic review based on inclusion and exclusion criteria. According to the results from a systematic review of 65 publications, the authors developed a restoration pathway and a visual processing framework for the first step, and a framework of visual stimuli, visual properties, and restoration for the second step.

Keywords: restorative effect; human stress; restorative built environment; visual stimuli; visual properties; attention; observer's goals; immersive virtual environments (IVEs); scientometric analysis

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1. Introduction

In general, stress occurs when there are not enough available resources in the environment to meet individual needs [1]. For example, poor quality housing, residential crowding, and insufficient daylight increase psychological distress [2]. Conversely, environments allowing users to effectively meet their needs would decrease stress (G. Evans & Cohen, 1987). Thus, there is no doubt that the surrounding environment is a key issue affecting human stress [3]. Since people spend over 85% of their time indoors, built environments can be considered the most important environment impacting human stress [4]. An increasing amount of empirical research has been reported on how built environments affect an individual's overall stress. For example, office and health care settings have been examined broadly to find the relationship between indoor environments and 'individuals' needs [5]. This exceptional attention was paid for plenty of reasons, including improving 'workers' performance to achieve more productivity [6]. The effects of the built environment on stress were discussed to explain the relationship between the physical features of the workspace and stress [7]. Additionally, environmental elements such as chronic noise could affect

stress in other contexts such as industry [8]. Thus, the literature shows the potential of built environments in changing stress.

Accordingly, built environments can be designed to help people to decrease stress. The concept of restorative environments has been proposed in the literature as environments where human stress can be decreased [9]. Two theories, Kaplan's Attention Restoration Theory (ART) [10] and Stress Recovery Theory (SRT) [11], explained the restorativeness of certain environments. Although these two theories are conceptually different, both processes complete each other [12,13]. Before going into depth in each theory, it is necessary to describe the concept of restoration associated with both theories [12]. In general, restoring psychological and physiological resources is the definition of restoration [14]. Although both theories focus on restoration, the type of sources restored is different. ART explains the process of restoration based on two types of attention: direct attention and effortless attention. Direct attention requires effort, while effortless attention requires no effortful fixation or cognitive effort [15]. The outcome of ART is a restoration of directed attention fatigue by removing the excessive cognitive load and involving effortless attention [12,13]. However, SRT focuses on restoration by reducing arousal levels and negative affect, including negative emotions and feelings such as fear, sadness, distress, etc. [14]. Accordingly, attention, mental fatigue, and cognitive load are linked with ART, and psychological arousal and negative affect are associated with SRT. In addition, there is a relationship between these two theories. For example, reducing arousal levels may be facilitated after the restoration from directed attention, and attentional fatigue can be considered a consequence of stress [13,16]. Thus, after integrating both theories, restoration can be redefined as a multi-phase experience that begins with attentional recovery and is followed by affective changes leading to stress reduction [12]. Therefore, restorative environments allow users to restore depleted psychological resources and decrease stress. Additionally, the literature has mostly studied natural environments as an example of restorative environments since the efficiency of nature in restoration is supported by both theories. For example, studies have shown that nature can mitigate the negative effects of stress [3]; and for people suffering from exhaustion disorder, visiting forest environments enhanced the recovery process [17]. Another study showed stress reduction in workplaces with access to green environments [18].

Moreover, individuals perceive ambient environments through basic human senses such as sight, touch, taste, and hearing linking with different human organisms such as eyes, ears, skin, nose, and mouth. A stimulus was defined as an agent as well as an environmental change affecting the activity of human organisms [19]. Thus, the information provided by the environment can be categorized into different types of stimuli based on human sensations such as visual, thermal, and acoustic. This study focuses on visual stimuli referring to any stimuli affecting human visual organisms through environmental experience. Accordingly, different types of individual objects along with their combinations such as images and window views, are instances of visual stimuli. In addition, the concept of attention plays an integral role in terms of visual stimuli and eye movements [20–22]. According to the Feature Integration Theory, the contrast between visual properties such as color, intensity, and orientation guides human attention [23]. Thus, the visual properties of visual stimuli may affect attention. In addition, based on the relationship between restoration and attention discussed earlier, human attention to visual stimuli of the restorative environment may affect the restoration process. Thus, visual stimuli and their properties may explain the potential of different environments in evoking restoration.

A design of a restorative built environment simply begins with the integration of natural objects indoors and is called biophilic design [24]. Accordingly, adding visual stimuli, including natural objects such as water, plants, green walls, and artwork depicting nature to the environments could make them restorative. Although the literature widely supports the advantages of restorative environments [25–27], various factors may lead to the failure of design intentions in real restorative environments such as financial restrictions, psychological factors, design restrictions, and durability along with visual factors such as visual distraction, complexity, and boredom [28–30]. Thus, a lack of good understanding

of factors affecting restoration may cause restorative environments to fail in meeting their design expectations such as stress reduction in actual environments. As discussed earlier, visual stimuli and their properties may be considered as one of the factors changing the restoration effect. For example, landscapes with natural stimuli were reported to be more restorative than ones with people as visual stimuli [31], and the same virtual environment designed with different visual stimuli varying in material and shapes resulted in different restoration [32,33]. In terms of visual properties, different landscapes including trees with different colors (green, yellow, and red) were employed to study restoration [34]. Additionally, the location of plants could affect employees' health [35]. As it can be seen in the literature, the impact of visual stimuli and properties was limited to specific individual objects, mostly natural objects such as plants [36]. However, there is less known about the impact of other visual stimuli as well as non-natural objects and their properties on restoration. For example, how the color of walls covered with natural objects such as green walls may affect human attention or how the size of non-natural objects in a restorative office environment may guide attention to the non-natural objects. Thus, the lack of understanding of non-natural objects and their properties in the design stage of restorative environments may lead to the failure of design intentions. Therefore, the key to this study is investigating the impact of visual stimuli and properties in built environments including both natural and non-natural objects with their visual properties and the relationship between them that may change attention and restoration. Results from this study may help architects and engineers to manipulate visual stimuli and properties to increase the restoration effect of occupants and create restorative environments.

In addition, the literature shows that designers employed different methods to deliver restorative environments in the design stage. For example, researchers investigated the restoration potential of forests delivered through images [37–40], and immersive virtual environments (IVEs) [41–43]. Different delivery methods may intervene in the efficiency of restorative environments since employing images, and IVEs can change the visual properties compared to the real environments. For example, the screen size and resolution may affect the image quality in computer-based studies [44–46]. Moreover, virtual reality headsets offer a wide range of visual features and different resolutions, brightness, and color affecting the visual properties of rendered images [47,48]. Thus, the possible impact of the delivery method on changing visual properties needs to be considered, specifically when the goal is to understand the visual stimuli and properties in the context of restorative literature. For that, the authors explored the type of delivery method used in the literature to study the impact of visual stimuli and their properties.

This paper is further organized as follows. In Section 2, the methodology of the paper is explained. Section 3 describes the process of scientometric analysis and systematic review of publications. Results from reviewed papers are presented through different frameworks to understand research themes and corresponding challenges. Lastly, Section 4, the conclusions, briefly summarizes the findings, which provide researchers an understanding of the importance of visual stimuli and properties in designing restorative built environments.

2. Research Methodology

To achieve the study objective, the authors performed a literature review in two main steps (Figure 1). The first step provides the required knowledge for the second step of the review.

- Step 1: The authors explored two different fields of study separately to understand:
  - (1) How restoration is processed through exposure to restorative environments, in particular, reviewing restoration studies to understand the physical elements and human responses associated with the restoration process.
  - (2) How the visual perception of environments is processed, in particular, reviewing visual studies to understand the types of visual stimuli and properties processed through different stages of visual processing.

- Step 2: The second step emerges from the results from the first step to understand how visual stimuli and properties of restorative environments may affect the restoration process.

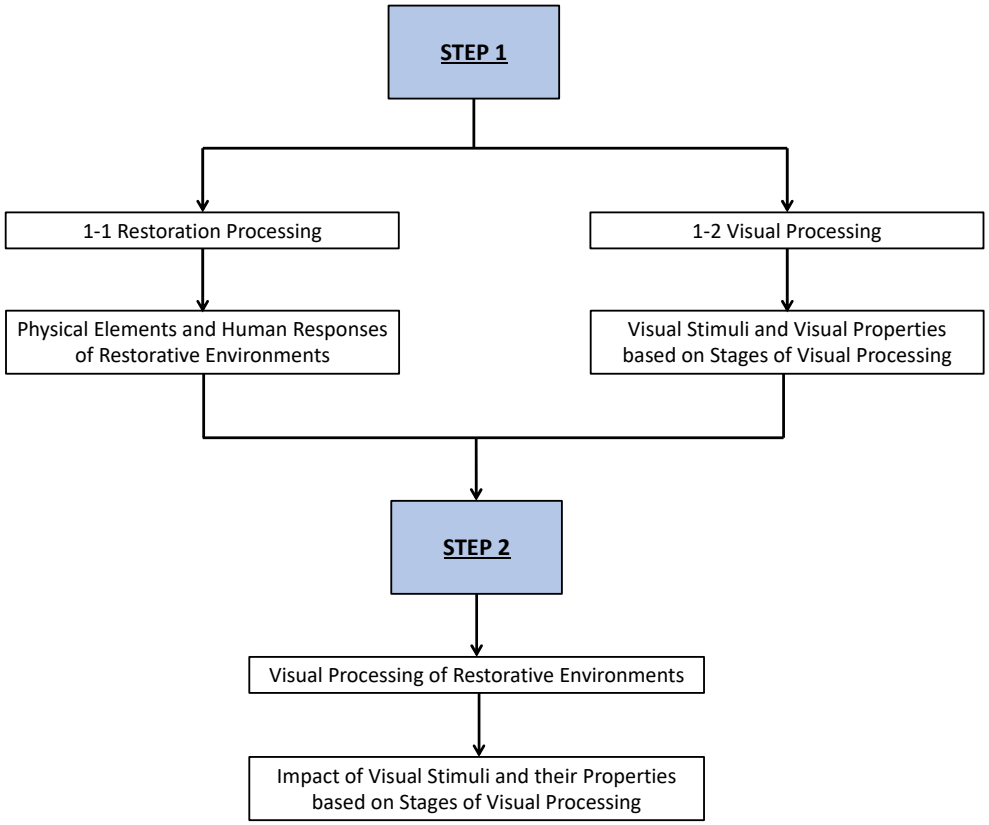

Figure 1. Two steps of conducting a literature review.

The literature review was conducted by combining scientometric analysis with a systematic review. Scientific knowledge areas are objectively mapped by researchers using scientometric analysis, whereas systematic review helped researchers detect the research themes and challenges [49]. Scientometric analysis is an appropriate method when there is a need to choose articles from a large source of data [50]. A large number of documents can be divided into groups with similar characteristics called clusters [51]. Clusters can be generated using different algorithms, such as log-likelihood ratio (LLR) algorithm that produces clusters with the highest quality [52]. The LLR algorithm represents the unique aspect of a cluster that can aid researchers in discerning the specific fields studied particularly in the cluster [53]. Additionally, LLR can create cluster labels chosen from the titles of publications. Thus, the focus of each cluster can be identified according to the labels [49], and unrelated articles can be excluded by removing clusters with labels less related to the focus of the review.

Figure 2 shows the relationship between scientometric analysis and systematic review including search, exclusion and inclusion criteria used for both analysis and review. The keywords for each step of the review were searched on the Web of Science (WoS) website. A search range was set within the titles, abstracts, and keywords of publications. In addition, the authors limited the search to articles published between 2000–2021 since the application of biophilia into the built environments occurred after 2000 [24]. Published peer-reviewed journals, conference proceedings, and books have been included in this research. The authors also limited the search to the publications from the most related categories according to each step of the review. After conducting scientometric analysis, the publications were selected for the systematic review by removing unrelated clusters and clusters with a small number of publications. The reason for removing small clusters is

that the cluster's properties, such as labels, are significantly affected by a specific document in small clusters [53]. Thus, the authors decided to remove clusters containing less than 20 publications. Then, the top 5 publications from each cluster with the highest coverage value referring to the number of cited references in each cluster were selected for the systematic review. In addition, each cluster was manually screened to find publications including the cluster's labels in their title. The process of finding keywords, scientometric analysis, and reviewed papers were explained separately for each step of review in the following sections.

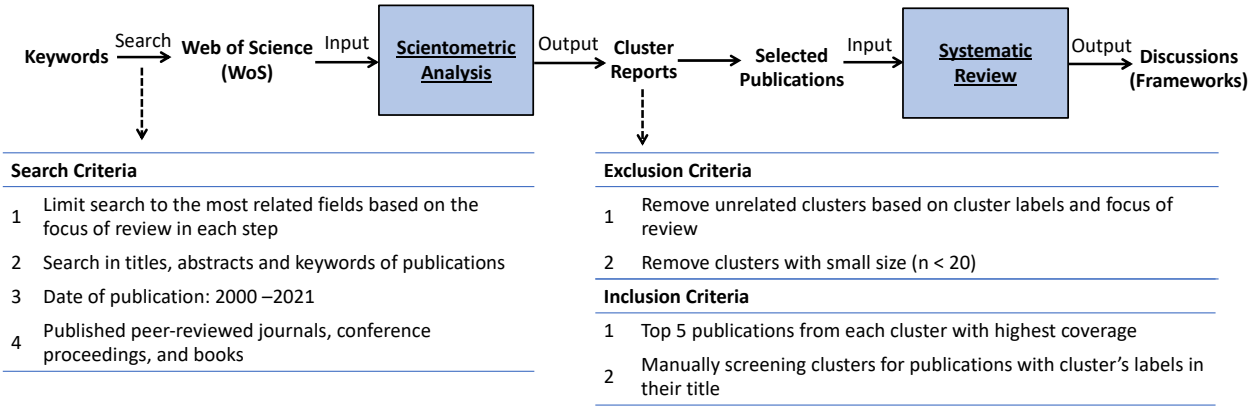

Figure 2. Relationship between scientometric analysis and systematic review including search, exclusion, and inclusion criteria.

2.1. Keywords and Search Strategy

Figure 3 summarizes the processes of finding keywords and the total number of publications used for scientometric analysis in each step of the review. The following processes were employed for each step:

1. First step:
   - 1.1 Restoration processing: Since ART and SRT explain the restoration process, "attention restoration" and "stress recovery" were searched separately in WoS as main keywords. After applying search criteria, the numbers of publications for each search are 386 publications for "attention restoration" and 1702 for "stress recovery". Then, the top 10 highly cited publications from each search result were fully reviewed to identify the most relevant keywords to be combined with two main keywords. Thus, WoS searched again with these keywords: (attention restoration) AND (restorative environment OR natural environment OR urban environment OR green space OR restorative component) OR (stress recovery) AND (restorative environment OR natural environment OR urban environment OR green space OR restorative component). A total of 956 articles were found after applying the search criteria and limiting the search results to the relevant fields (Environmental Sciences, Environmental Studies, Public Environmental, Occupational Health, Psychology Multidisciplinary, Urban Studies, Engineering Environmental, Green Sustainable Science Technology, Construction Building Technology, Engineering Civil, Psychology, Psychology Experimental, Behavioral Sciences, Architecture, Psychology Applied, Computer Science Interdisciplinary Applications, Engineering Multidisciplinary). The recent update to this search was conducted in January 2022.
   - 1.2 Visual processing: Since the focus of this step is to understand the visual processing of visual stimuli and properties, "visual stimuli" and "visual properties" were selected as two main keywords. The reason for limiting the keywords to these two terms is to broadly search visual fields without focusing on specific visual concepts such as "visual comfort", etc. The analysis

of the results from this search may help us to detect the most relevant terms associated with the visual processing of visual stimuli and their properties in literature without bias. Thus, "visual stimuli" and "visual properties" were searched throughout the most relevant fields of research associated with visual processing such as Psychology Experimental or Psychology or Behavioral Sciences or Psychology Multidisciplinary or Psychology Developmental. A total of 627 publications were found. In addition to the search criteria, the authors manually screened the title and abstract of publications to exclude studies using visual stimuli inconsistent with the definition of stimuli in this study. Finally, a total of 597 publications were chosen for scientometric analysis. A recent update to this search was conducted in January 2022.

2. Second step: In this step, to review the visual stimuli and properties of restorative environments, four major keywords, "attention restoration", "stress recovery", "visual stimuli", and "visual properties" were combined based on the following search rules: (attention restoration) AND (visual stimuli OR visual properties) OR (stress recovery) AND (visual stimuli OR visual properties). After applying the search criteria, a total of 55 publications were picked for the scientometric analysis. The recent update to this search was conducted in January 2022.

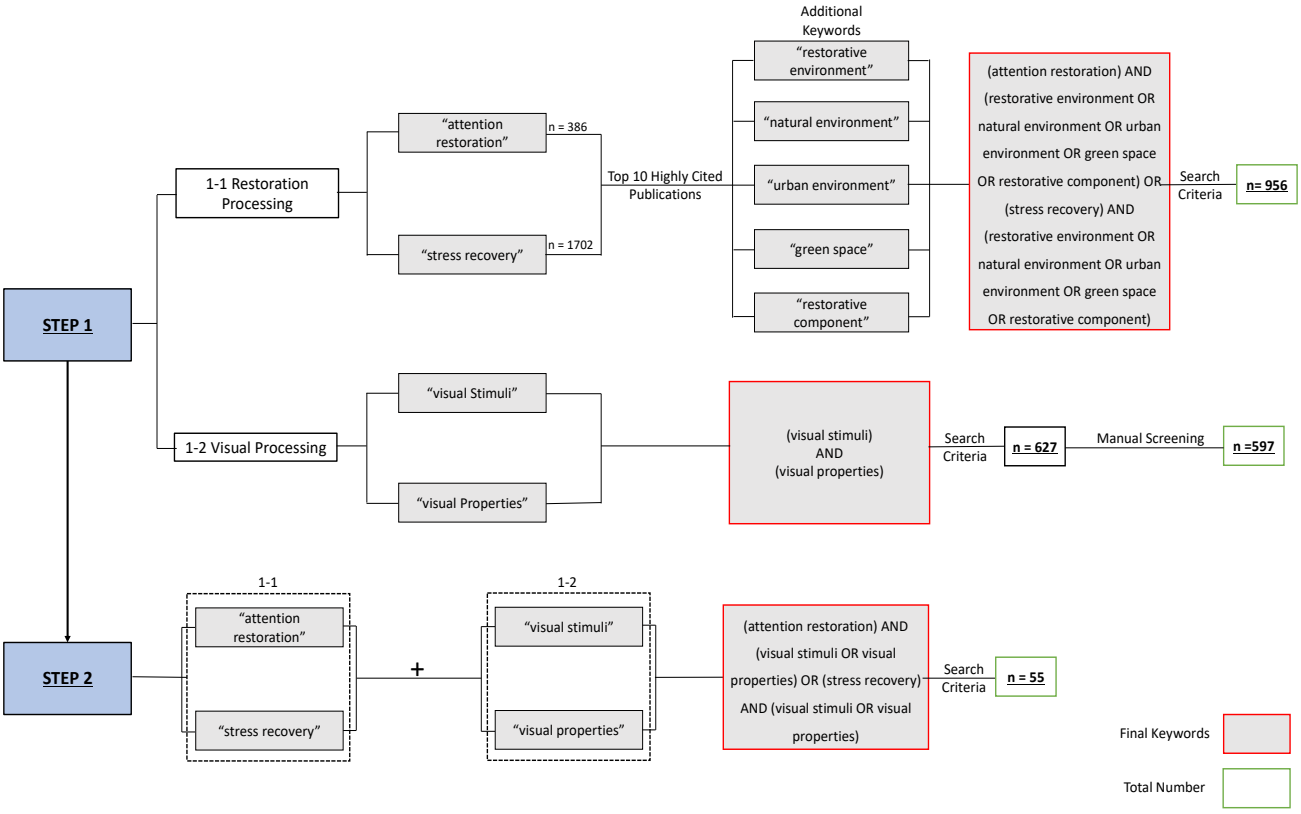

Figure 3. Keywords and the total number of publications for scientometric analysis of each step of the review.

2.2. Scientometric Analysis Method

Scientometrics is a quantitative method for establishing a scientific connection through citation-based domain visualization resulting in a quick familiarization with a field of study [54]. Scientometric analysis can be conducted based on different processes, such as co-citation, co-author, and co-word. Among these different methods, co-citation analysis is the most common technique in quantitative studies to discern the intellectual structure of a scientific knowledge field and identify patterns through groupings created from

high co-citation trails [53]. Therefore, the authors performed a co-citation analysis in this review study.

The authors used CiteSpace for the scientometric analysis, since this software provides co-citation analysis using progressive network analysis grounded on a time-slicing strategy. The output of this application presents the properties of the network such as most cited references and burst strength [53] to identify emerging trends, intellectual turning points, and existing connections and gaps [49]. Moreover, CiteSpace uses the clustering function to group the network by analyzing both citers and cited references. Hence, the intellectual base of each cluster was defined by cited members, and citers were directly related to the research fronts formation [53]. Understanding the relationship between clusters is useful in terms of identifying emerging areas and existing gaps [55]. According to the cluster reports, the authors picked the most important publications to review.

3. Scientometric Analysis and Systematic Review

3.1. Step 1-1: Restoration Processing

3.1.1. Properties of Network

A total of 956 publications were analyzed by CiteSpace software (version 5.6.R3, https://novapublishers.com/shop/citespace-a-practical-guide-for-mapping-scientific-literature/, accessed on 2 March 2022). Table 1 presents detailed information on the top 5 most cited references of this network. The first two publications explained two main theories of restorative environments: Attention Restoration Theory (ART) [10] and Stress Recovery Theory (SRT) [11]. According to ART, recovery from fatigue resulting from directed attention could be recovered in natural environments, and stress recovery was faster in natural environments based on SRT [11]. Moreover, the restoration benefits of natural environments were investigated in the next three references [13,56,57]. Thus, according to ART and SRT, the benefits and features of natural environments were most studied in terms of restorative environments. Regarding the date of publication, the first three publications were published before 2000, while the date of publications for analyzed documents was set to 2000–2021 according to the research criteria. This result may explain the importance of ART and SRT in recent studies focusing on restoration.

Table 1. Top 5 most cited references of network for the first step of the review, restoration processing.

No	Year	Author	Title	Freq
1	1995	Kaplan S	The restorative benefits of nature: Toward an integrative framework [10]	402
2	1991	Ulrich RS	Stress recovery during exposure to natural and urban environments [11]	370
3	1989	Kaplan R	The experience of nature: A psychological perspective [56]	326
4	2003	Hartig T	Tracking restoration in natural and urban field settings [13]	225
5	2008	Berman MG	The Cognitive Benefits of Interacting with Nature [57]	185

In addition to the frequency, the burst citation is a complementary metric measured as the properties of the network. If the frequency of citations associated with an article remarkably fluctuated during a short period, it was detected as a burst citation [53]. Thus, burst citation was used to detect influential publications. Table 2 describes the top five publications with the strongest burst citation along with the period of the time that the bursts occurred. A review of publications showed that researchers investigated the restoration from different points of view, including (1) different types of environments: outdoor environment [58] and play area [59], (2) different ages: children [59], (3) psychological aspect of restoration: fascination, and esthetic pleasure [60], and (4) activity: driving [61]. In addition,

natural experiences evoke greater restoration compared to other environments [62]. Thus, restoration and stress recovery studies included a broad area of research associated with various fields of study.

Table 2. Top 5 references with the strongest burst citation for the first step of the review, restoration processing.

No	Year	Author	Title	Begin	End
1	2001	Kuo FE	Coping with Poverty Impacts of Environment and Attention in the Inner City [58]	2003	2013
2	2001	Taylor AF	Coping with Add the Surprising Connection to Green Play Settings [59]	2003	2013
3	1997	Herzog TR	Reflection and attentional recovery as distinctive benefits of restorative environments [60]	2003	2013
4	1991	Hartig T	Restorative effects of natural environment experience [62]	2001	2010
5	1998	Parsons R	The view from the road: implications for stress recovery and immunization [61]	2002	2016

3.1.2. Cluster Analysis and Systematic Review

The next step in co-citation analysis is to explore clusters to find articles for the systematic review. In total, 12 co-citation clusters were identified through the log-likelihood ratio (LLR) algorithm. As explained earlier, cluster labels were automatically generated by LLR from the title of publications in each cluster. Since the 956 articles analyzed by CiteSpace include irrelevant publications, manually screening of clusters is needed to exclude unrelated clusters. As shown in Figure 4, cluster #4 "urban soundscape", cluster #7 "adult personality", and cluster #8 "psychological task" were removed because of little correlation with the restoration and stress studies. In addition, clusters #9, 10, 11, and 12 were excluded due to the small size of the cluster. The remaining clusters need to be discussed to establish the intellectual base of the restoration process.

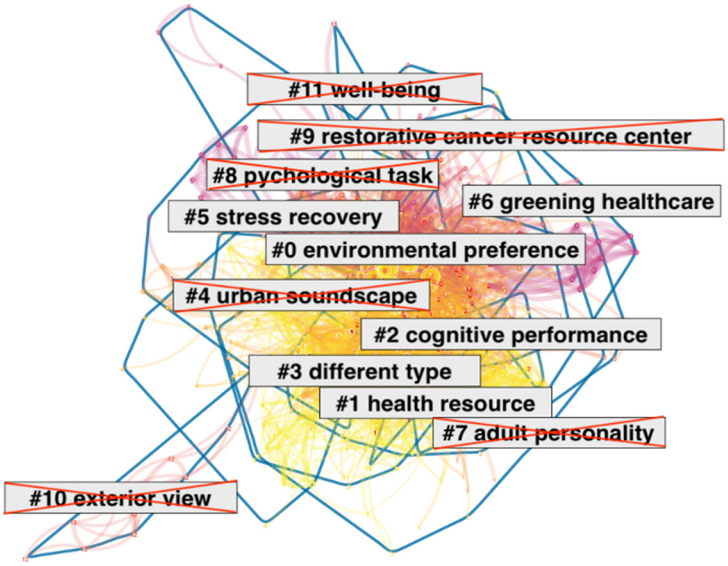

Figure 4. Co-citation clusters of the network for the first step of the review, restoration processing.

Detailed information of each cluster is presented in Table 3. In addition to the size, and mean year, silhouette measures the average homogeneity of a cluster [63]. Clusters with a high silhouette value (>0.7) have high reliability in terms of clustering results [49]. Thus, clusters #0 and #1 are less reliable and contain publications from areas different from

the cluster's label. The top five documents of each cluster with the highest coverage value representing the number of articles cited by documents were selected as representative documents. In addition, the list of articles in each cluster was manually screened to find publications with the cluster label in their title. The authors employed a systematic review of these articles to identify research themes.

Table 3. Cluster information and documents for the first step of the systematic review, visual processing.

Mean Year	Cluster ID	Size	Silhouette	Cluster Label	Documents for Systematic Review (*n* = 38)
1999	#0	166	0.697	environmental preference	[64–70]
2010	#1	141	0.555	health resource	[71–75]
2008	#2	74	0.744	cognitive performance	[25,69,76–80]
2011	#3	61	0.763	different type	[42,43,81–87]
2001	#5	47	0.851	stress recovery	[31,88–93]
1992	#6	25	0.963	greening healthcare	[94–97]

The "environmental preference" cluster contains studies establishing the relationship between the concept of preference and the restoration effect. According to the literature, there is a preference for natural environments [65] because of the benefits of nature exposure, such as stress reduction and negative affect [67] and improving health [68,69]. In addition, the layout properties of the environments, such as beauty, play a mediating role by impacting the individuals' preferences and changing the restoration potential consequently. For example, the participants reported that natural environments were more beautiful than built ones, while natural environments evoked higher restoration [64]. Since the layout properties are highly dependent on the type, properties, and design of objects in the environment, the natural objects (such as plants) and their properties (such as biodiversity and species) may change the layout properties (such as beauty associated with preference) [70]. Accordingly, the difference between environmental objects and their properties may change the layout properties affecting the restoration potential and stress reduction through preference.

The authors reviewed the publications from clusters #1 and #6 together, since both clusters focused on the health benefits of natural settings, including outdoor environments such as urban green spaces [66,67] and urban forests [73] or indoor environments [74]. Nature exposure can improve different dimensions of mental health, such as cognitive functioning, emotional well-being, positive emotions, mental restoration, vitality, and relaxation [71,72,75]. The term "greening healthcare" was introduced as a supplementary process to aid conventional healing and reduce care-related expenses [94,95]. In addition to the benefits of nature, researchers explored the impact of different types of objects, such as trees [73] and plants [74], along with the layout properties such as intensity [74], biodiversity, level of disturbance, proximity, and accessibility on health [96].

In cluster #2, articles focus on cognitive performance as a positive impact of natural exposure, specifically the cognitive performance of students [25,76–78]. Researchers applied various methods to measure cognitive performance, such as sustained and selective attention test (bells test), working memory test (digit span test) [25,76], and d2 test comparing mental load across the two classrooms with and without plants [77]. Accordingly, cognitive performance is associated with various psychological dimensions such as attention, memory, and mental load. The impact of natural environments on cognitive performance is assessed through these psychological dimensions. In addition, different types of natural objects are impacting cognitive performance [69,79,80]. Thus, there is a need to detect

the relationship between objects, their properties, and the psychological dimensions of cognitive performance as important measurements of restorative environments.

Restoration and stress recovery of different types of environments were explored in cluster #3, such as different types of forests [81,82], rural landscapes [83], and natural outdoor environments [84]. The difference between environments originated from the difference in objects' properties such as type, number, and the design of objects, providing different layout properties of the environments. For example, the restoration potential of forests is different based on the type of trees (deciduous vs. coniferous) [81] and the presence of different objects such as trees, water, grass, bench, and pool [82]. In addition to the impact of objects, different layout properties may influence stress reduction differently. The layout's colors, such as green [84,86], blue [84], and grey [86], were applied to differentiate between environments in terms of the presence of green objects (e.g., trees and plants) and water. Another layout property is the openness of spaces. For example, green spaces were defined in four levels: open, partly open, partly closed, and closed based on the vegetation, and open space was reported as the highest positive effect environment and closed as the lowest [86]. However, factors other than vegetation need to be considered in defining openness, such as structure, function, scene dimension, and observer's view [98]. Thus, different environments had different impacts on restoration effect and stress recovery, and the objects and layout properties of each environment could partially explain this difference.

In cluster "stress recovery", the potential of outdoor natural environments such as forests and urban parks in recovery from stress was discussed [31,88,89]. In addition, researchers introduced nature-based rehabilitation environments known as rehabilitation forests [90] and rehabilitation gardens for stress reduction [91,92]. Thus, the environments designed for rehabilitation can facilitate stress recovery. However, the potential of environments in stress reduction is different based on layout properties. The impact of layout properties on stress may occur through changing the environmental preference [90], consistent with the first cluster discussed earlier. Thus, recovery from stress can be facilitated in preferred environments, and layout properties such as openness, light, a good view, cleanliness, and peacefulness can increase preference [90,93].

3.1.3. Developing a Restoration Pathway

Based on the results from the first step of the review, a conceptual pathway of restoration can be proposed based on the following elements and the relationship between them (Figure 5):

- Main elements: A restoration pathway begins with "natural exposure" and ends with evoking "restoration".
- Cluster labels: Cluster labels were employed to explain how publications from different clusters impact the restoration pathway. As can be seen in Figure 3, the "different type" of natural environments may affect the restoration pathway through changing "cognitive performance" and "preference". In addition, "restoration" is directly associated with "stress recovery", and "health". Thus, higher "restoration" may improve "stress recovery", and "health".
- Causal elements: According to the clusters review, "object" and "layout" properties of natural environments may impact the "restoration" by changing the type of environments. Any physical item that can be visually perceived by an individual is referred to as an "object". The primary properties of the "object" such as color, size, and shape help observers identify them. In addition, the "object" can be added to or removed from environments. Moreover, "layout" properties are defined as perceptual properties of the scene resulting from the objects and their design in the scene, such as naturalness, beauty, openness, and depth [98,99]. Thus, "object" and their properties can change the "layout" properties. In addition to the changing type of environment, "object" and "layout" properties may affect "cognitive performance", "preference", "stress recovery", and "health" directly. This may be used to design restorative environments other than nature without changing the type of environment.

For example, adding natural objects and layout properties found in nature into interior environments such as office spaces may increase "preference" and improve "cognitive performance" leading to "restoration" while the type of the environment (i.e., office space) is the same.

- Examples/relevant terms: Examples of "object" and "layout" properties studied in the literature were added to give a better understanding of properties changing the type of environment. In addition, "attention", "mental load", and "memory" were added as relevant terms to the "cognitive performance" since they may affect the restoration pathway by changing "cognitive performance".

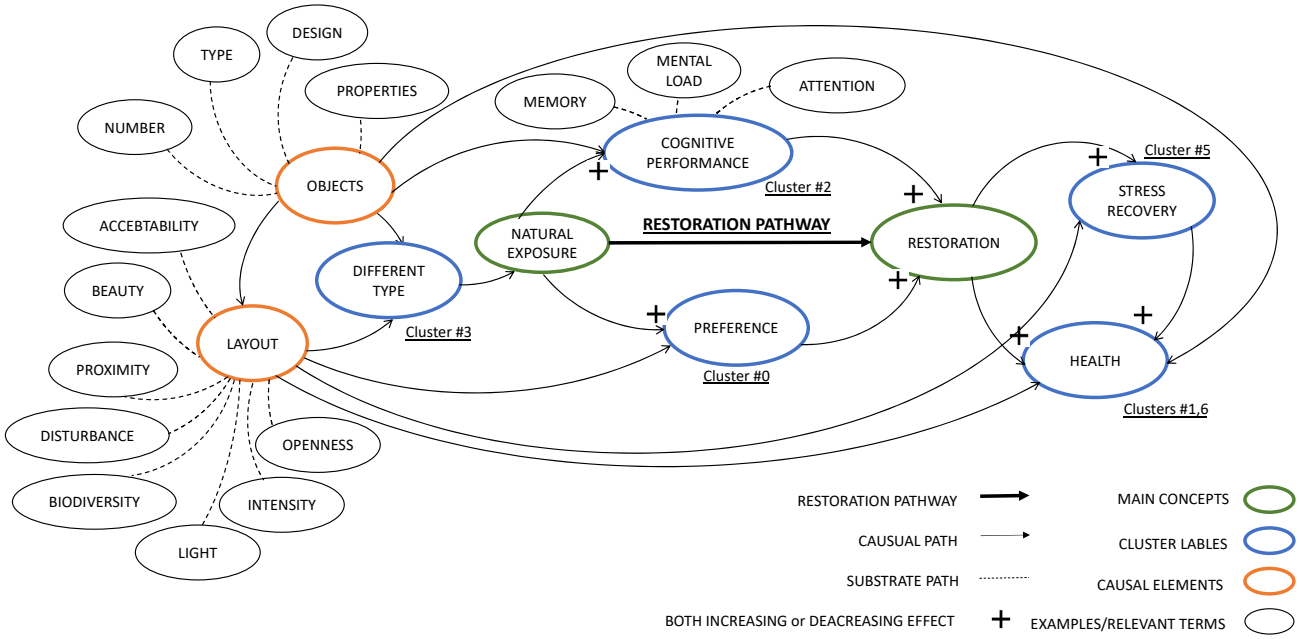

Figure 5. A Restoration pathway.

3.2. Step 1-2: Visual Processing

3.2.1. Properties of Network

A total of 597 publications were analyzed by CiteSpace software (version 5.6.R3, https://novapublishers.com/shop/citespace-a-practical-guide-for-mapping-scientific-literature/, accessed on 2 March 2022). Table 4 presents detailed information on the top 5 most cited references of this network. The first two publications introduced Psychophysics Toolbox, and VideoToolbox has been used to generate visual stimuli for experimental studies [100,101]. This interface between MATLAB and various libraries draws complex two and three-dimensional scenes from points, lines, and polygons and shows them on screen in a limited time [102]. The other three studies focused on the concept of attention as well as the feature-integration theory of attention [23], and the impact of visual stimuli and their properties on attention [103,104]. Since human visual processing is functioning under attentional control [105], attention plays a key role in terms of human visual processing. In general, there are two attentional controls, top-down and bottom-up [103,104]. Top-down control refers to attention intentionally captured by objects, properties and regions associated with the observer's goals and tasks. In contrast, bottom-up control refers to attention involuntarily captured by salient stimuli with no intentions [106]. Thus, there is a relationship between visual processing of the scenes with observer's goals and attention. In the following, the authors explain the observer's goals, visual processing, and the scene definition in the context of this study to understand the existing relationship between them.

Table 4. Top 5 most cited references of network for the first step of the review, visual processing.

No	Year	Author	Title	Freq
1	1997	Brainard DH	The Psychophysics Toolbox [100]	71
2	1996	Pelli DG	The VideoToolbox software for visual psychophysics: transforming numbers into movies [101]	41
3	1992	Folk CL	Involuntary Covert Orienting Is Contingent on Attentional Control Settings [103]	33
4	1980	Treisman AM	A Feature-Integration Theory of Attention [23]	32
5	1980	Posner MI	Orienting of Attention [104]	27

Human lives comprise complex daily tasks including a variety of simple tasks. For example, to turn on the TV, it is needed to search the scene for the remote, identify it, navigate to it, and then pick up the remote. Thus, humans carry behavioral goals to accomplish daily tasks such as scene recognition, scene categorization, visual search, navigation, and action that can be achieved through visual processing of the scenes [99]. In general, visual processing occurs through two main stages, global and local processing:

- Global processing: Global processing is the initial stage of visual processing of the scene that happens through broadly analyzing the scene without attentional control to specific locations [105,107]. A general category of the scene known as gist can be obtained from the global processing as early as 13 ms after scene presentation, and it continues until 300 ms of exposure [99,108]. Since global processing is limited to the properties of the scene, the scene itself can be considered as the main visual stimuli in global stage. Global properties contain three types:
    1. Low-level properties: Structural and physical properties such as edges, spatial frequency, and color, can be computed through simple models [98,99]. These properties mostly include image statistics.
    2. Layout properties: Perceptual properties of the scene resulting from the objects and their design in the scene, such as naturalness, beauty, openness, and depth [98,99].
    3. High-level properties: Functional properties of the scene associated with the semantic category and scene categorization [99]. For example, the forest scene is different from the kitchen according to their function.
- Local processing: Local processing involves consecutive processing of limited locations, including individual objects, to present detailed information such as the object's identity and properties [107,109]. Thus, objects as visual stimuli and their properties are known as local properties, playing a key role in this stage of visual processing. In addition, local processing operates under attentional control [109,110]. Thus, the saliency or contrast between visual stimuli in terms of basic properties such as color, shape, and size can capture attention [111–113]. Two types of visual stimuli were commonly used by researchers to study attention: target stimuli (designed to capture attention) and non-target or distractor (any stimuli other than the target stimuli). The relationship between target and non-target stimuli can affect attention through sharing similar or dissimilar visual properties. For example, objects less similar to the target but share the same relational property, such as color, may capture attention [114].

In addition, there are two distinct definitions of the scene, stimuli-based and interaction-based [99]:

- Stimulus-based: The scene contains foreground objects arranged in a background providing a specific layout. The focus of this definition is objects as stimuli, and observers can process the scene by simply observing the scene. Images are mainly used to deliver the stimulus-based scene to recognize and categorize the scene.
- Interaction-based: The scenes are defined as an environment where people as observers are embedded in and can interact with them. The type of interaction can be explained

by the observer's goals discussed earlier such as visual search, navigation, and action. Thus, the focus of the definition is the observer's interaction with the scene, mostly objects to accomplish the goals.

Figure 6 shows the impact of observer's goals on two stages of visual processing and scene definition. Accordingly, the observer's goals are the same in two stages of visual processing and scene definition. Thus, observers may recognize and categorize the scenes through global processing consistent with the stimuli-based definition. In addition, visual search, navigation, and action can be obtained from interaction with objects in the scene associated with the local processing, and interaction-based definition of the scene.

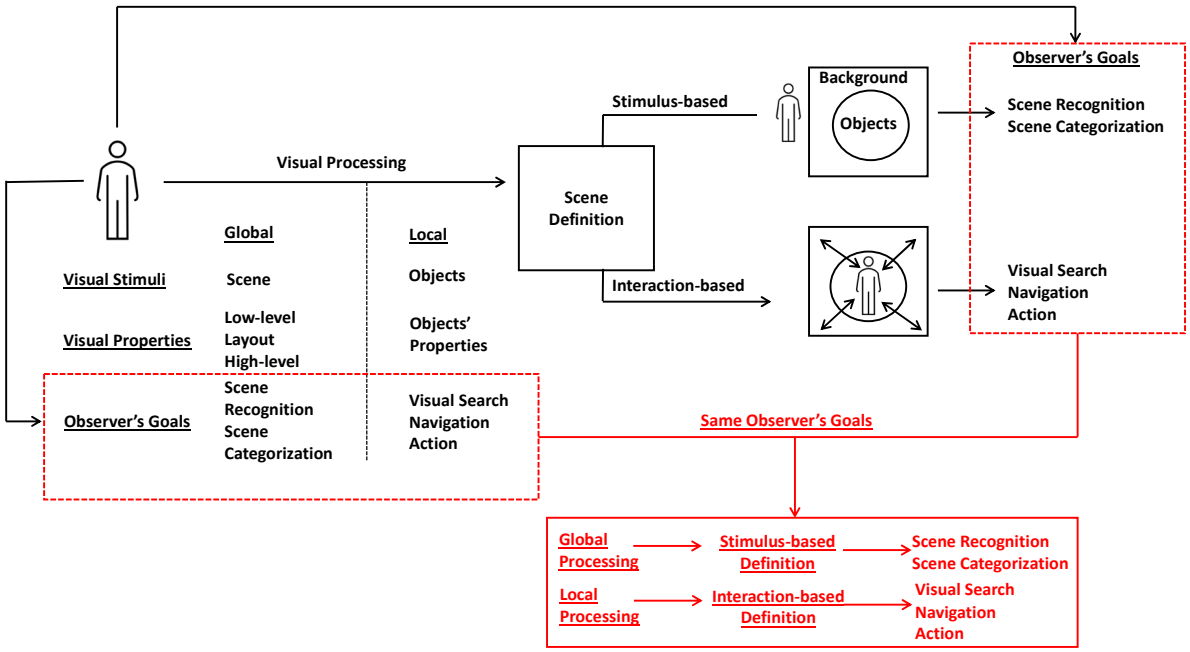

Figure 6. The relationship between visual processing, scene definitions, and observer's goals.

In addition to the citation frequency, the burst citation was used to detect influential publications. Table 5 shows the top 5 publications with the strongest burst citation along with the period of the time when the burst occurred. The high citation for the first two articles [100,101] showed that researchers widely used Toolbox software (https://www.softwaretoolbox.com/, accessed on 2 March 2022), discussed earlier, between 2012 and 2019. In addition, the impact of the observer's goals and task dimensions on attention were highly cited by researchers between 2005 and 2012 [103,105], and after that, between 2016 and 2021 [115]. This showed that researchers were focused on identifying factors other than the object's visual properties affecting attentional control to successfully define the target and distractor objects while designing the environments. The existing relationship between global and local processing affecting the time of visual processing may aid researchers in identifying those factors. For example, objects that match with the scene category or observe goals are identified faster than irrelevant objects [99]. Since attention is required for object identification in the local processing stage, observer's goals and object's properties may change attentional pattern [99,116,117].

Table 5. Top 5 references with the strongest burst citation for the first step of the review, visual processing.

No	Year	Author	Title	Begin	End
1	1996	Pelli DG	The VideoToolbox software for visual psychophysics: transforming numbers into movies [101]	2012	2019
2	1997	Brainard DH	The Psychophysics Toolbox [100]	2013	2018
3	1994	Bacon WF	Overriding stimulus-driven attentional capture [118]	2005	2010
4	2012	Awh E	Top-down versus bottom-up attentional control: a failed theoretical dichotomy [115]	2016	2021
5	1992	Folk CL	Involuntary Covert Orienting Is Contingent on Attentional Control Settings [103]	2008	2012

3.2.2. Cluster Analysis and Systematic Review

For this step, 20 co-citation clusters were identified through the log-likelihood ratio (LLR) algorithm. Since CiteSpace analyzed the cited documents in 597 articles, including irrelevant publications, manually screening of clusters was performed to exclude unrelated clusters based on the following criteria. According to the highest cited references and burst detection, the attention-related clusters were selected for the critical review. As shown in Figure 7, the title of cluster #0 was correlated with attention. In addition, after manually screening clusters, one publication from cluster #8 was added to the manual review since the cluster explored the visual properties of images introduced as a type of delivery in the first step. Thus, the publications from cluster #0 with the highest coverage of references were selected to be systematically reviewed, along with one article from cluster #8 (Table 6).

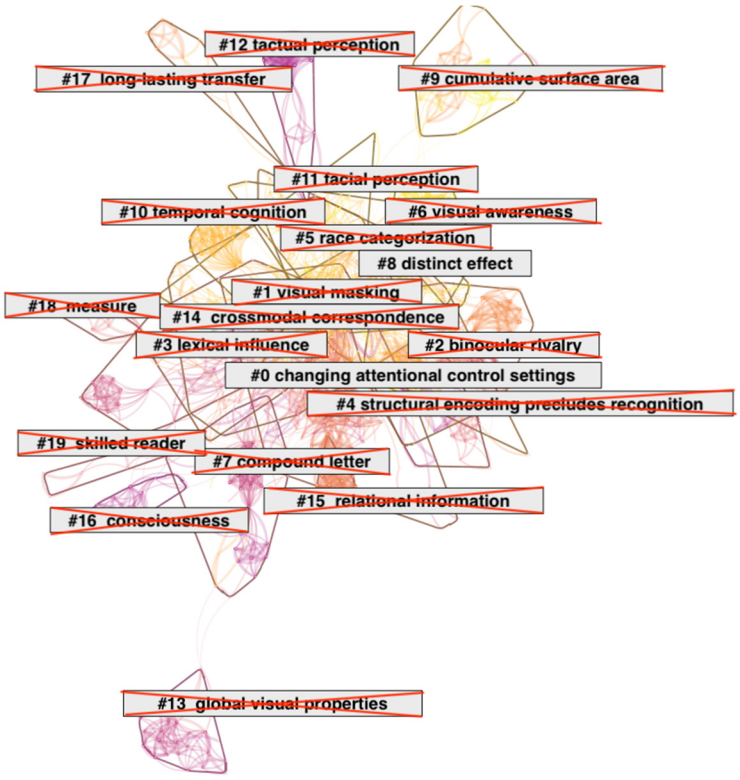

Figure 7. Co-citation clusters of the network for the first step of the review, visual processing.

Table 6. Cluster information and documents for the first step of the systematic review, visual processing.

Mean Year	Cluster ID	Size	Silhouette	Cluster Label	Documents for Systematic Review (n = 10)
1996	#0	96	0.864	changing attentional control settings	[106,111–114,116,117,119,120]
2002	#8	35	0.919	distinct effect	[121]

The first cluster contains publications investigating the control of spatial attention under different settings. As explained before, the saliency and contrast between visual properties [111–113] along with the observer's goals [119] may affect attention under two types of attentional control: top-down and bottom-up [111,112]. Regarding the observer's goals, task-irrelevant properties may capture unique aspects of a scene. For example, visually unique and unexpected properties but task-irrelevant, such as dissimilar colors, could hold attention [114]. To detect attention, researchers applied various methods such as response time and eye movements during visual search tasks [108,113,114]. Thus, attention and eye movements are highly related, and shifting of attention is associated with eye movements [111].

Cluster #8 contains an article exploring the impact of image properties on human emotions [121]. Accordingly, low-level image properties such as color, spatial frequency, and contrast analyzed through global processing may affect psychological responses such as emotions by changing the layout properties and esthetic. Thus, there is a relationship between low-level and layout properties that may affect human psychological responses in the global processing stage.

3.2.3. Developing a Visual Processing Framework

Figure 8 summarizes the review results to understand the relationship between human, visual processing, scene, and to develop a visual processing framework. In general, observers carry behavioral goals to accomplish their daily tasks through two different visual processing stages, global and local. The scene, and its properties (low-level, layout, and high-level) are processed through global processing leading to scene recognition and categorization. However, the focus of local processing is objects and their properties to accomplish visual search, navigation, and action. In addition, the stimulus-based scenes delivered by images can be used for global processing and the real interaction-based scenes for local. As discussed earlier, scenes and their objects may impact the observer's goals which can be discussed in each stage of visual processing:

- Global processing: Visual properties of the scene may impact recognition, and categorization. For example, spatial layout properties facilitate the early stages of recognition [99], and the time needed for scene recognition is different based on spatial frequencies [122]. However, it is still unknown whether there is a preference toward particular frequencies or observers choose to process the visual properties required to accomplish a specific task [123]. In addition, the impact of objects can be discussed through the concept of diagnostic as perceptual information facilitating goals [99]. For example, a tree is highly diagnostic in recognizing the scene as a forest compared to a flower. Thus, integrating highly diagnostic objects in the scene may lead to fast recognition.
- Local processing: Since attention plays a key role in local processing, the impact of objects and their properties on goals may be explained through attention. For example, objects matching with goals would capture more attention and identify faster than other objects. These types of objects can be categorized as target objects while distractors are objects different than goals. In addition, the contrast between visual properties of objects may change attention According to the Feature Integration Theory [23]. Attention to the target objects may facilitate goals such as visual search. In addition, the impact of objects can be discussed through the concept of affordance. According to the interaction-based definition, the scenes are the environment providing the chance of action known as affordance [124]. Thus, object affordance may affect the visual search [99].

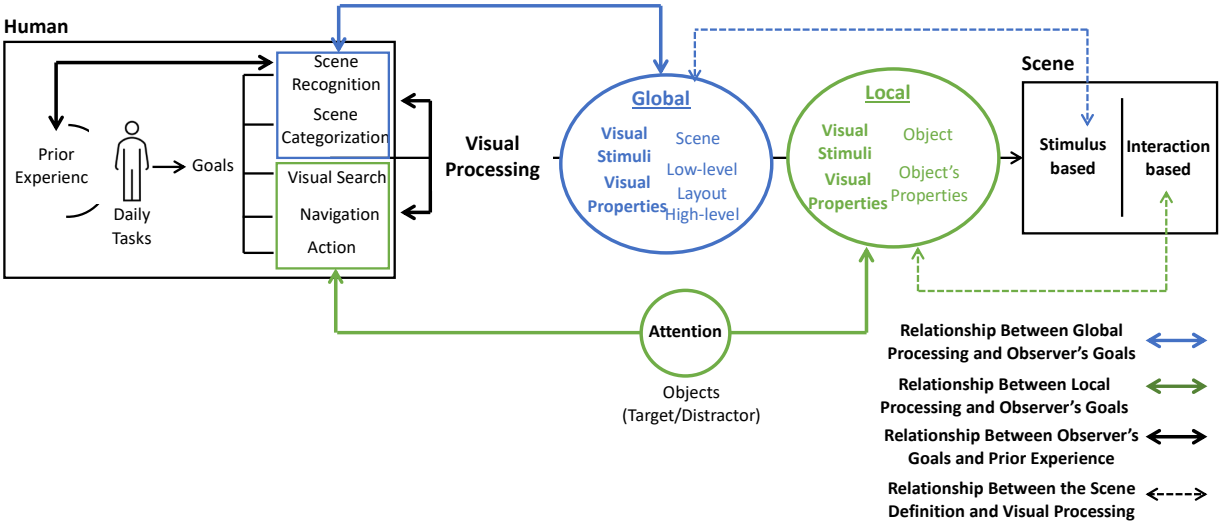

Figure 8. A visual processing framework.

In addition, there is a relationship between different goals. For example, scene recognition is associated with visual search and navigation [99]. Thus, it is not possible to exactly map the impact of properties with observers' goals. Moreover, the observer's prior experience may influence the recognition of the scenes, and scenes that match with the experience would be recognized quickly [125].

3.3. Step 2: Visual Stimuli and Visual Properties of Restorative Environments

3.3.1. Properties of Network

A total of 55 publications were analyzed by CiteSpace software (version 5.6.R3). Table 7 presents detailed information on the top 5 most cited references of this network. Accordingly, the most cited references of the network are the same as the first step, restoration processing (Table 1). Thus, ART [10] and SRT [11] were the most cited references for this network, and natural environments as a restorative environment were broadly investigated by publications [13,56,57]. In addition, there are two references exploring the impact of natural sound in restorative environments, which are not the focus of this study [126,127]. Moreover, no publications were detected as burst citations for this step.

Table 7. Top 5 most cited references of network for the second step of the review, visual stimuli, and visual properties of restorative environments.

No	Year	Author	Title	Freq
1	1995	Kaplan S	The restorative benefits of nature: Toward an integrative framework [10]	25
2	1991	Ulrich RS	Stress recovery during exposure to natural and urban environments [11]	18
3	1989	Kaplan R	The experience of nature: A psychological perspective [56]	17
4	2010	Alvarsson JJ	Stress Recovery during Exposure to Nature Sound and Environmental Noise [126]	16
5	2003	Hartig T	Tracking restoration in natural and urban field settings [13]	13
5	2013	Annerstedt M	Inducing physiological stress recovery with sounds of nature in a virtual reality forest—Results from a pilot study [127]	13
5	2008	Berman MG	The Cognitive Benefits of Interacting with Nature [57]	13

3.3.2. Cluster Analysis and Systematic Review

For this step of review, 10 co-citation clusters were identified through the log-likelihood ratio (LLR) algorithm. Since CiteSpace analyzed the cited documents in 55 articles, including irrelevant publications, manual screening of the clusters was performed to exclude unrelated clusters. As shown in Figure 9, clusters #1, 4, and 8 (including audio-related terms such as auditory and soundscape) and clusters #5, and 6 (including art, and medical-related terms) were removed from the systematic review. After manually screening publications in the remaining clusters, the related articles with the highest coverage were selected for systematic review (Table 8).

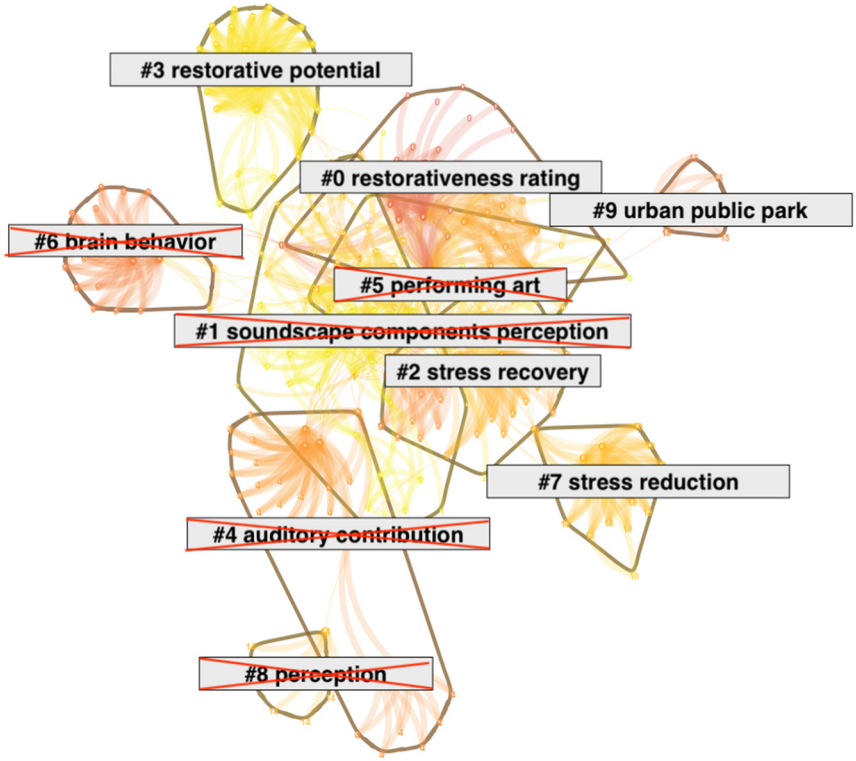

Figure 9. Co-citation clusters of the network for the second step of the review, visual stimuli, and visual properties of restorative environments.

Table 8. Cluster information and documents for the second step of the systematic review, visual stimuli, and properties of restorative environments.

Mean Year	Cluster ID	Size	Silhouette	Cluster Label	Documents for Systematic Review (*n* = 17)
2005	#0	44	0.861	restorativeness rating	[34,39,40,128–137]
2002	#3	30	0.961	restorative potential	
2003	#2	37	0.878	stress recovery	[138–140]
2004	#7	18	0.973	stress restoration	
1995	#9	6	1	urban public parks	[141]

Publications from clusters "restorativeness rating", "restorative potential", "stress recovery", and "stress restoration" containing experimental studies examined the impact of visual stimuli and properties on human restoration and stress reduction. In addition, the last cluster includes one article introducing quantitative methods to rate the restoration potential of the environments. According to the restoration pathway presented in the first step, the restoration begins with natural exposure (Figure 5) and includes the visual processing of the restorative scene (Figure 8). As discussed in visual processing, the visual

stimuli and properties are different based on each step of visual processing. In addition, the observer's goals, prior experience, and the scene definition may affect visual processing. Thus, the authors reviewed the impact of visual stimuli and properties on restoration in each global and local stage by considering the observer's goals, prior experience, and the scene definition (Figure 10):

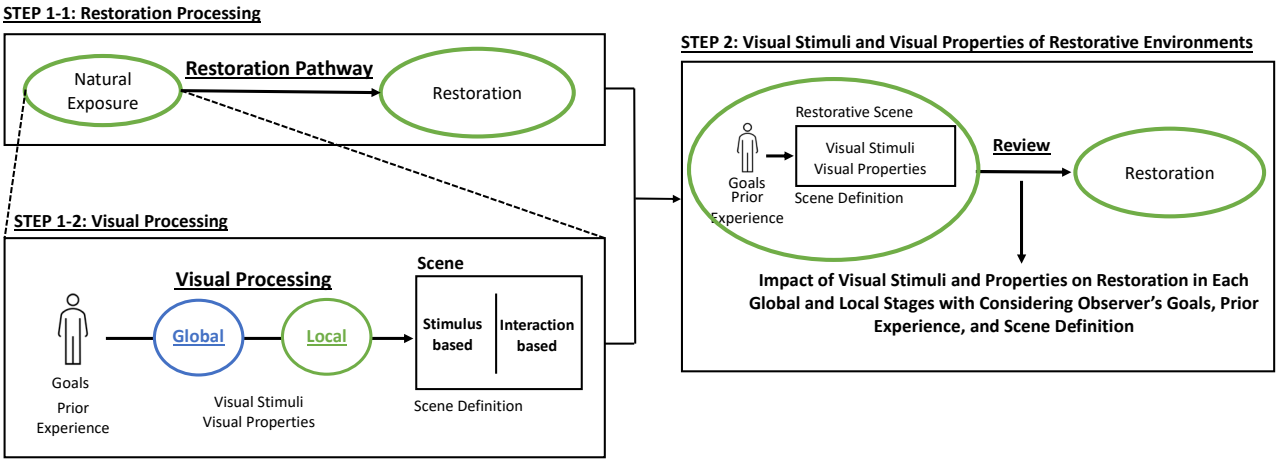

Figure 10. Second step of review based on the restoration path and visual processing framework.

Global Visual Processing of the Restorative Scenes

Literature focused on the global processing of natural and urban scenes as visual stimuli (without focusing on objects) to identify visual properties affecting restoration. Employing the scenes as visual stimuli is consistent with the results from the first step, and stimulus-based definition of the scene. According to the review of publications, two types of visual properties may affect restoration in global stage: low-level and layout properties. Nature and urban images are different in terms of low-level properties such as spatial frequency and spectral power [132]. For example, natural scenes are composed of less high spatial frequency compared to urban scenes [128]. However, it is not the case that natural scenes as a category have less energy in high spatial frequency [142]. It may be the case that visual processing is facilitated by high spatial frequency information in urban scenes and low-spatial frequency information in natural scenes. Since the observer's goals are limited to scene recognition, and categorization in this stage, recognizing natural and urban scenes may be linked to the different global properties. Thus, specific visual properties are required to recognize the scene as a natural scene. In addition, recognition can be facilitated if the information presented in the scenes is matched with prior experience. For example, observers may fail to recognize and categorize the natural scenes in the presence of non-natural objects. Thus, the presence of highly diagnostic objects in recognizing natural scenes such as trees may decrease the impact of non-natural objects.

Furthermore, it is still unknown whether the amount of restoration evoked through global processing of the scenes is sufficient or local processing is needed to achieve restoration. For example, a study [132] suggested the impact of low-level properties on restoration is not significant, and local processing, including object recognition and spatial information is required to complete the restoration. In addition, the impact of low-level properties on restoration may be explained by the relationship between low-level and layout properties. For example, spatial frequency and spectral power are used to assess the naturalness and aesthetic of images [132]. Thus, low-level properties may change the restoration by impacting the layout properties. Therefore, the authors proposed future studies examining the low-level and layout properties of restorative scenes. Moreover, the layout properties such as openness, heterogeneity, visual access, movement ease, and lighting may change the restoration through global processing of the scenes [136,138–140]. Researchers defined and categorized layout properties from different perspectives. For example, different degrees of

openness were defined based on plant arrangement, locations, and distance that may block the view to the background [34,130] while other studies defined openness as a property providing prospect and view over scenes [31,136]. Thus, there are different definitions for a single layout property which may confuse. In addition, researchers proposed new layout properties based on their study goals. For example, "landscape design intensity" was proposed by [39] as layout properties to show the ratio of artificial objects added to the natural landscapes, or "perceived sensory dimensions" was defined by [140] containing various layout properties associated with nature such as culture, prospect, social, space, rich in species, refuge, and serene. Therefore, there is a need to have the same definition of the layout properties in the literature.

The literature mostly used images delivered through monitors and desktop screens to study the impact of visual stimuli and properties during the global processing of the scenes [39,40,130,132]. However, the screen size and resolution may affect the image quality in computer-based studies [44–46]. Thus, before choosing a delivery method, researchers may need to understand and control the possible impact of the delivery method on visual stimuli and properties since they may interfere with the study's goals. Four reasons may explain the application of images as a common delivery method for global processing:

- According to the stimulus-based definition of the scene, images can be used to deliver the scenes. Since there is no need for observers to interact with the scene, scene recognition and categorization can be obtained from the processing of images.
- Since global processing occurs in the early stages of visual processing, a few seconds of exposure is enough for scenes to be globally processed. Thus, to detect the impact of visual stimuli and properties, participants needed to be exposed to various scenes with different properties, which is impossible in reality; so, researchers employed a series of images varying in visual stimuli and properties and presented each image for 5–15 s.
- Based on the definition of low-level properties in the second step, these properties can be obtained from images [98,99,143]. Thus, images are the best delivery methods for examining low-level properties.
- Images are widely used by researchers from cognitive science, psychology, neuroscience, and interdisciplinary studies as an effective delivery method for evoking emotions and human responses [144].

In terms of human responses, most studies in the literature measured human preference after the global processing of the scene [39,128,134]. According to the first step of the review, preference is associated with layout properties. In addition, low-level properties such as spatial frequency and scene category can be obtained from the global process of the scene affecting the preference [145]. Thus, preference can be considered as a proper measurement associated with restoration resulting from global processing. In addition to using surveys to measure preference, some studies employed the eye-tracking method as a physiological measurement linked with preference [39,128,136]. However, the data obtained from eye-tracking data, such as fixation and blink rates, are mostly related to the attention associated with the local processing. Therefore, using eye-tracking methods with the global stage may be linked with identifying areas of interest containing objects with high potential to capture attention based on their properties, and then, these objects will be locally processed in the next stage of visual processing [107].

Local Visual Processing of the Restorative Scenes

Some literature focused on the local processing of objects as visual stimuli (after global processing of the scenes) to identify visual properties affecting restoration. For example, the visual properties of objects may affect restoration through the existence of different objects (water vs. trees) [129], or the same object (trees, plants) with different visual properties, such as the color of trees (red or yellow), and flowering [34], type of trees (foliated, defoliated, and evergreen) [130], and biodiversity [131]. Thus, objects and their visual properties are the focus of local processing. According to the interaction-based definition, restorative

scenes can be defined as places where observers may search for natural objects and navigate toward them to restore their psychological resources. Since in real restorative environments, objects other than natural objects may exist in the scene, target and distractor objects can be defined based on the role of attention. Thus, target objects of restoration scenes are designed to capture attention, while distractors contain other objects and background clutter. Distractor objects may explain the performance gap that exists between design and real restorative scenes. Thus, there is a need to consider the role of distractors in achieving design intentions. In addition, the visual properties of natural objects as target objects in restorative scenes can be manipulated to capture attention to natural objects by providing contrast and saliency.

Although the goal is capturing people's attention to target objects, the relational information between target and distractor objects might affect design goals [114]. For example, attention can be captured by dissimilar objects presenting the same visual properties (such as color) as the target object. Thus, replacing natural objects such as plants with non-natural objects with the same properties (e.g., green color) may evoke restoration [14]. Therefore, visual stimuli, even non-natural objects sharing the same visual properties as natural objects, may capture attention and evoke restoration. In addition, saliency can be obtained by increasing the saliency of individual stimuli and set size regardless of visual properties [113]. However, increasing the number of natural objects in the scene might decrease a sense of security and familiarity [146]. For example, the number of plants and type of arrangement would decrease the permeability and perceived security, leading to obtaining a less restorative effect [147]. Thus, increasing the number of natural objects as visual stimuli does not necessarily lead to a higher level of restoration, and further studies are needed to detect the relationship between visual stimuli' saliency and contrast with perceived senses intervening in restoration.

Since a longer exposure time is required for local processing and interaction with the scenes [107,109], some studies used other methods such as virtual reality to deliver images while providing an immersive experience to complete the restoration [148]. For example, [149] used a 360-degree images of outdoor scenes in virtual reality for three minutes. Virtual reality provides greater control over experimental stimuli in psychology when various scenes need to be presented at different times to naturally induce human reactions [150]. However, tighter control of the scene may cause a difference in visual properties between real and virtual scenes [151]. In most cases, the field of view is simulated to create virtual stimuli, while factors outside of the field of view may affect visual properties in real environments. For example, lighting and reflection from the surfaces of objects from out of the field of view can affect the visual properties of the scene. This difference between real and virtual scenes may raise concerns if the goal of the study is to understand the impact of visual stimuli and properties in real scenes by using virtual reality as an experimental apparatus.

In addition, virtual reality headsets offer a wide range of visual features, such as different resolutions, brightness, color, and field of view, affecting the visual properties of rendered images [47,48]. For example, saliency and contrast are highly dependent on basic visual properties such as color, shapes, and luminance, and transferring real environments into the virtual might change the saliency and contrast of the scene. Moreover, researchers also used simulated models to study the impact of visual properties since it is easier to modify the visual properties in simulated scenes [34,130] However, simulated environments are different from real environments in terms of visual properties based on the level of visual details included [152]. Thus, before the application of virtual reality and simulated models, it is necessary to detect the changes in visual properties resulting from delivery methods or simulated models.

In terms of human responses, eye-tracking methods can be used to measure attention associated with the local processing of objects. Thus, attention toward target objects, mostly found in restorative environments such as natural objects, would be compared with distractor objects to assess design efficiency.

3.3.3. Developing a Framework of Visual Stimuli, Visual Properties, and Restoration

According to the results from the second step of the review, the authors suggested a framework to discuss the relationship between visual stimuli and their properties with human restoration along with observer's goals and the scene definition (Figure 11). A restorative built environment can be obtained by integrating natural objects into the built environments. Thus, human visual processing in a restorative built environment contains the visual processing of multiple restorative scenes based on human fields of view. In addition, a restorative scene can be defined based on stimulus-based and interaction-based definitions associated with global and local processing, respectively, and the visual processing of restorative scenes may impact human restoration in each stage. The natural and urban scenes are globally processed, while their visual properties, low-level, and layout properties are different. In addition, there is a relationship between low-level properties and layout properties, such as the association of spatial frequency with naturalness [132]. Moreover, scene recognition and categorization may be influenced by two factors: (1) scenes and their properties, and (2) prior experience. Thus, these two factors can be manipulated to facilitate recognition of natural scenes to increase restoration.

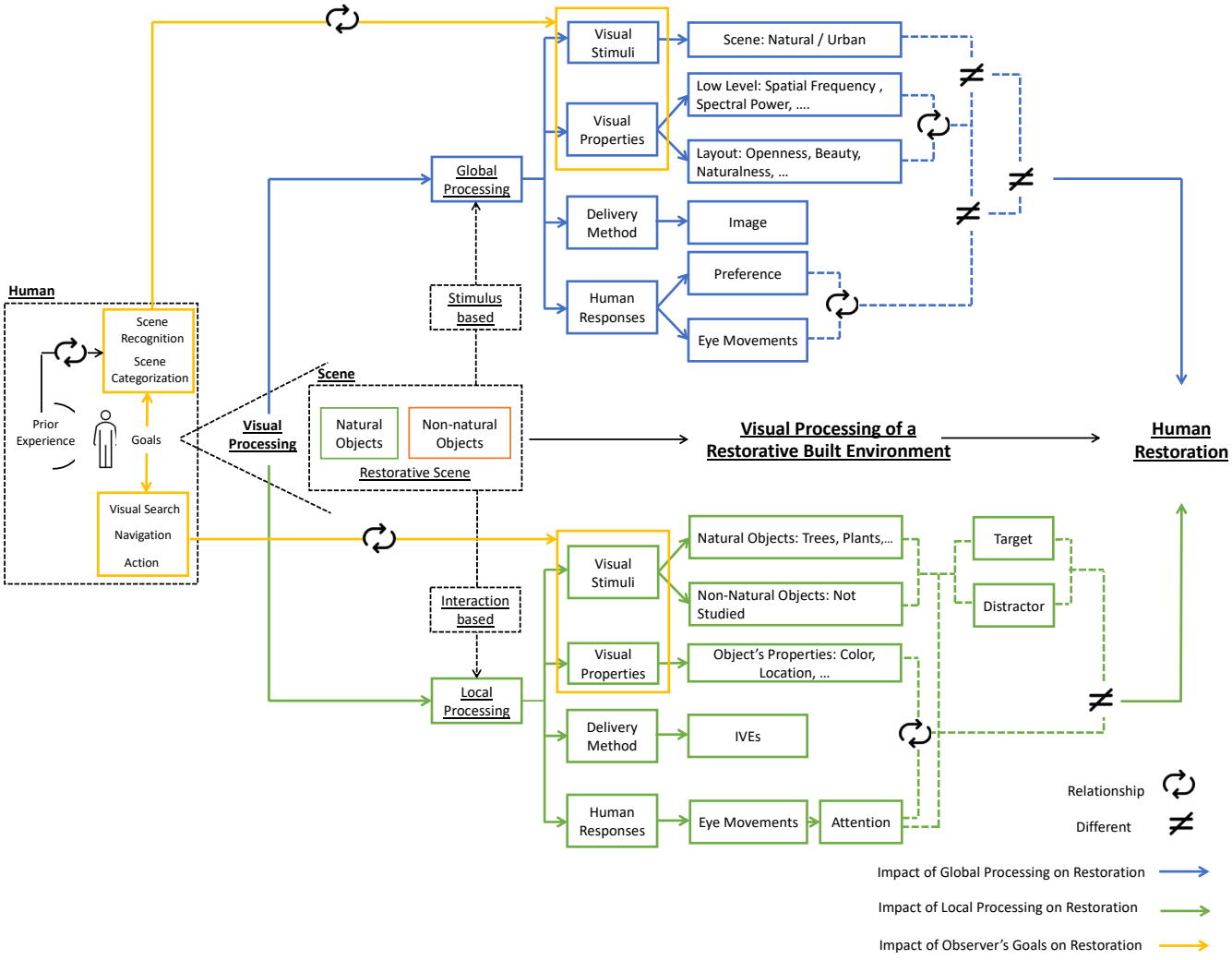

Figure 11. A Framework of visual stimuli, visual properties, and restoration.

In terms of human responses, preference and eye movements are used to assess the impact of visual stimuli and properties. While these two responses are relevant, human preference and eye movements are different in natural and urban scenes. Since natural and urban scenes are different in terms of low-level and layout properties, different

human responses can be explained by the impact of the visual properties of the scene. In summary, global processing of restorative scenes may affect human restoration through the type of scene, natural and urban containing different visual properties and leading to evoking different human responses associated with the restoration as well as preference and eye movements.

The natural and non-natural objects are locally processed while their visual properties such as color, location, etc. are different. However, literature mostly focuses on natural objects and their properties and fails to consider the impact of non-natural objects and their properties on restoration. In addition, the objects and their properties may affect visual search, navigation, and action. Thus, there is a need to facilitate behavioral goals by manipulating objects and their properties. In terms of restoration, natural objects and their properties can be deigned to easily identify and navigate in the scene to obtain restoration. In terms of human responses, eye movements are used to assess human attention to various visual stimuli since attention plays a key role in the local stage of visual processing. Accordingly, the target and distractor objects can be defined based on attention to different objects, particularly in the design process of restorative environments. Thus, target objects are natural objects designed to capture attention while distractors are non-natural objects. Therefore, the design intention is to guide attention to target objects and minimize human attention to distractors which can be achieved by changing the visual properties of objects. In summary, the local processing of restorative scenes may affect human restoration through the different amounts of attention captured by the target and distractors containing different visual properties.

In addition, the delivery method is different in global and local processing. Restorative scenes were delivered in images while literature used IVEs to deliver restorative scenes throughout the local processing. Both these delivery methods can aid designers in understanding the impact of visual stimuli and properties. However, designers may need to understand and control the possible impact of the delivery method on visual stimuli and properties since they may interfere with their goals.

4. Conclusions

A restorative built environment can be designed by integrating natural objects into the built environment. However, various factors may affect a restoration pathway leading to the failure of design intentions in real restorative environments. This review showed that the visual processing of restorative scenes is associated with human restoration. The impact of visual processing can be discussed through two stages, global and local processing different in visual stimuli and properties. Thus, scenes and their properties such as low-level and layout properties may affect restoration on global stage while local processing focuses on the impact of objects and their properties. In addition, observers carry out behavioral goals relevant to their daily tasks. Goals such as scene recognition and categorization can be achieved on the global stage, and visual search, navigation, and action are the goals of local processing. Since scenes, objects, and their properties affect the observer's goals, the impact of visual stimuli and properties on restoration may be explained through the goals. Moreover, the observer's prior experience can be another factor influencing the goals.

In terms of scenes, there are two definitions, (1) stimulus-based linked with scene recognition and categorization, and (2) interaction-based linked with visual search, navigation, and action. Accordingly, the images can be used to deliver stimulus-based scenes to the observers for recognition and categorization. However, real exposure to the scene is required for human interaction and visual search, navigation, and action. Thus, the literature suggested using IVEs as a delivery method, since IVEs provides a more realistic experience by immersing the applicants. However, when the goal is to employ virtual reality as an experimental apparatus, it is important to detect the difference between virtual, and reality in terms of visual properties. First, virtual reality provides tighter control over stimuli presentation that may block the factors impacting visual properties from out of the field of view, and secondly, virtual reality headsets offer a wide range of visual features and

different resolutions, brightness, color, and field of view affecting the visual properties of rendered scenes. In summary, the impact of visual stimuli and their properties on restoration can be studied in global and local stages of visual processing of a restorative built scene. However, it is necessary to consider the observer's goals and prior experience along with the scene definition, and type of delivery method to study restoration concerning visual stimuli and their properties.

5. Limitations and Future Studies

In this study, co-citation analysis was employed to generate clusters and their labels through LLR algorithm from the title of publications. However, there are other types of analysis as well as co-author or co-keywords and other algorithms such as latent semantic indexing (LSI) or mutual information (MI) for generating clusters that may change the cluster's size. Since a minimum threshold was used to remove clusters with small sizes, future studies are needed to test different analyses and algorithms for generating clusters with different sizes.

Moreover, there is a limitation in choosing the keywords, particularly in terms of visual processing. The authors limited the keywords to two terms, "visual stimuli" and "visual properties" according to the purpose of this study. Although the concept of attention was detected in the review results, there might be other relevant terms such as visual comfort that were not addressed in this study. Thus, future studies should consider including other visual concepts in generating keywords.

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