A review of the limitations of Attention Restoration Theory and the importance of its future research for the improvement of well-being in urban living

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Abstract
Attention Restoration Theory (ART; Kaplan, 1995) is the predominant theory identifying characteristics of nature that are thought to make it restorative. Albeit, these characteristics lack operational definitions, thus generating several methodological challenges in critically assessing ART. For example, a major component of restoration within the ART framework is soft fascination, which is an involuntary capturing of attention, but not in a dramatic fashion. However, there is no empirical support of nature's ability to innately hold attention, and this poor understanding contributes to the challenges in developing an operational definition of soft fascination. We describe attributes of stimuli that are known to capture visual attention (e.g., salience; Ruz & Lupiáñez, 2002) and consider whether such attributes are consistent with the notion of soft fascination. Since ART evolved from literature on aesthetics and environmental preferences (e.g., Kaplan, 1987), a review of this literature may inspire new ways to define restorative characteristics of nature, and thereby, promote the implementation of these characteristics into built environments. Thus, the purpose of this paper is to review and integrate relevant literature from multiple subfields of psychology to inspire research that can employ new methodology and ultimately better our understanding of the mechanisms underlying restorative environments.

Keywords: Attention Restoration Theory, aesthetics, directed attention, attention capture, visual perception

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Introduction

Throughout most of history, humans lived a more rural lifestyle, often referred to as "living off the land," supported by hunting, fishing, and farming. The industrial revolution seemed to have instigated the move from rural to urban areas. Now, about half our world population (4.128 billion people) lives in urban environments, and 68% of our population is expected to live in urban environments by 2050 (United Nations, 2018). In theory, urbanization can be beneficial for several reasons. Urbanization results in people living closely together, which has the potential to be more energy efficient, provide greater access to resources, and increase social cohesion. In reality, urban areas have not necessarily been an asset to human psychological well-being. Urban living is associated with additional stressors, like noise, crowding, and crime.

Importantly, urban environments are thought to be less emotionally and cognitively restorative compared to natural environments (van den Berg, Hartig, & Staats, 2007). Further, urban expansion reduces the amount of natural environments available. In turn, this can reduce the opportunity for interaction with nature and the recovery from fatigue and stress that is associated with nature interaction. Overall, urbanization poses an issue for human psychological well-being. Given these concerns, the question arises: How can we implement components of nature that are restorative into urban environments?

The purpose of this paper is not to be an exhaustive resource on literature citing the benefits of nature interaction, but rather, to integrate literature from different subfields that we believe may inspire new empirical research regarding the mechanisms underlying emotional and cognitive restoration and the implementation of restorative aspects of environments into urban areas. Towards that end, a review is needed of the major theory of cognitive restoration associated with nature, Attention Restoration Theory (ART; Kaplan, 1995). Further, this paper will highlight some gaps and methodological challenges in the literature supporting ART and attempt to integrate literature from information processing theory, resource theory, aesthetics, visual perception, and environmental psychology to inspire future research that may address shortcomings in the literature associated with ART. It was our aim to cite others fairly and appropriately and maintain an unbiased view in the literature that we included in this paper, but the reader should note that this paper is ultimately our interpretation of the relevant literature. We encourage readers to review original works and develop their own critical analyses of them.

Attention Restoration Theory (ART)

Attention Restoration Theory (ART) argues that exposure to nature after performing a demanding task that requires and depletes directed attention capacity (i.e., attention that is required to focus and inhibit distractions in support of difficult mental activity) will subsequently facilitate the replenishment of directed attention capacity (Kaplan, 1995). Further, ART postulates that *certain characteristics* of nature effortlessly grab bottom-up attention, which frees up the capacity for top-down, directed attention and leads to recuperation of directed attention fatigue. Therefore, in order for an environment to be considered restorative, it must contain certain characteristics, which are as follows:

- Soft fascination: An environment that promotes effortless attention distributed across aesthetically pleasing features of the environment (e.g., clouds, tree branching moving in the wind).
- Extent: An environment that is conceptually vast, such that one could get lost in it.
- Being away: An environment that allows one to engage in cognitive content outside of the current situation or need (i.e., day dreaming).
- Compatibility with one's goal: An environment that aligns with one's goal, and nature is thought to have an evolved compatibility with the human basic needs because it has contained the basic needs for survival throughout history.

A significant amount of empirical research on ART has been conducted. This research has presented a compelling case for the benefits associated with nature exposure, specifically improvements in cognitive (Kaplan, 1995), emotional (Hartig, Evans, Jamner, Davis, & Garling, 2003), and stress (Ulrich et al., 1991) outcomes. However, there remains a need to address some of the limitations of ART from how it has been previously assessed. We hope that this paper presents several unanswered research questions that others can pursue in addressing the challenges that research on ART presents. The next sections aim to address the following: (1) the lack of operational definitions of the characteristics purported to be important for restorative environments, (2) no empirical evidence that the soft fascination characteristic captures bottom-up attention and the mechanism underlying this attention capture, and (3) the inconsistent measurements of directed attention and an unclear explanation on how it is being depleted and subsequently replenished by nature interventions. Importantly, these sections present research and methodology from other subdisciplines that could be applied to help fill these gaps.

Measuring Characteristics of Restorative Environments

While ART proposes four characteristics thought to be necessary for an environment to be restorative, the measurement of these characteristics in a scene could be improved. Currently, researchers use self-report ratings of each of these characteristics in order to gauge if an environment is restorative (e.g., Perceived Restorativeness Scale; Hartig, Korpela, Evans, & Garling, 1997). While self-reports in research are valuable and informative metrics (see Muckler & Seven, 1992), the issue with this technique is that the perceived strength of these characteristics in a scene is being used to define the restorative quality of the scene without ever validating the need of these characteristics for restoration. Further, this methodology presents the potential for demand characteristics, or confounds in which participants may anticipate that researchers are predicting a greater positive response to nature compared to urban environments and therefore respond in a more positive way to nature. The current methodology for measuring the characteristics that are assumed to be important for restoration by ART needs to be further developed.

ART was originally inspired by the environmental preference literature that merged aesthetics and affective responses to environments. Thus, a review of this literature may provide inspiration for new ways to operationally define and then assess the four characteristics of restorative environments proposed by ART. According to ART, humans have an evolved preference for nature due to the survivability of natural environments. Kaplan postulated that environments that provide a good mental map or understanding of the physical environment enhance survivability and are preferred. Further, he assumed that humans are attracted to environments that inspire exploration. He proposed four aesthetic variables that are thought to be important for either understanding the environment or the ability to explore the environment crossed with the availability of information in the environment (immediate or inferred); these variables are presented in Table 1, and a brief explanation of each is provided below.

	Understanding	Exploration
Immediate	Coherence	Complexity
Inferred	Legibility	Mystery

Table 1. Kaplan's (1987) Aesthetic Variables Related to Environmental Preference.

Understanding the Environment: Coherence and Legibility

The proposed aspects of preferred scenes are coherence, or organization of the information in the scene, and legibility, which involves the ability to predict what is to follow in the scene if one were to explore it further. Coherence and legibility are assumed to be related to understanding of the scene, meaning there won't be a threat or unexpected event that would occur in the scene.

With regard to measuring these variables, structural coherence is thought to involve the configuration of the visual array. Coherence is thought to increase preference, which can also be explained by evolutionary psychology as an adaptive trait because it would afford a large number of elements to be chunked together as opposed to a several, smaller chunks. Structure can be achieved by an environment having redundant elements, properties that provide continuity, focality and by the grouping of elements, all akin to Gestalt principles. An application of Gestalt principles may afford a method of measurement for coherence and structure, but this would likely need to be self-reported as well. Legibility would be difficult to operationally define without asking people if they can predict what the environment would provide if it were to be explored more.

Exploring the Environment: Complexity and Mystery

Complexity and mystery are both thought to be important for exploration. Complexity involves the number of independently perceived elements in a scene, such that a highly complex environment has a large number of elements that are dissimilar and not easily grouped together. Complexity can be difficult to operationally define because it is unknown how people group items in unique environments together. Thus, it would be too simplistic to count the number of items in an environment to define complexity, as the grouping of items would not be accounted for. The relationship between complexity and aesthetic preference has an inverted-U shape, such that a moderate level of complexity results in the highest preference ratings. Ulrich (1983), who also studied the association between aesthetic variables and environmental preferences, cited the importance of complexity for preference as well.

On the other hand, mystery involves the notion that a scene appears to promise more information if an observer were to explore the scene further (e.g., a hill that one cannot see beyond). This, too, is an abstract variable that is difficult to measure. We think that depth/spaciousness and ground surface texture may be related to mystery and could be indicators of mystery. Specifically, depth and spaciousness are proposed to be important from an evolutionary perspective because a moving, exploring person would need depth to identify dangers and have opportunities to escape, whereas low depth may result in hidden dangers and fewer opportunities to escape the environment in the presence of danger. Thus, the relationship between depth and aesthetic preference is linear, such that greater depth is associated with greater preference (Ulrich, 1983). Furthermore, ground surface texture is important for depth perception, such that uniform, smooth textures can make depth perception easier and thus increase preference compared to rough, uneven textures (Ulrich, 1983).

Measuring Visual Attributes of Scenes

The aforementioned aesthetic variables proposed by Kaplan in 1987 are not much easier to measure than the four restorative characteristics proposed by him in 1995. Additionally, to our knowledge, it is presently unclear how the aesthetic variables of interest are related to his four restorative enviroment characteristics. Because of this, aesthetic and visual perception research may offer new characteristics of restorative environments that were not proposed by Kaplan.

Indeed, recent research efforts have focused on identifying quantitative low-level visual features (i.e., computed from decomposing images, more bottom-up driven) and high-level visual features (i.e., semantic, more top-down driven) related to people's aesthetic preference for certain environments and perceived naturalness of environments. Importantly, preference and naturalness are thought to underlie the restorative effect (Kaplan, 1995; Ulrich et al., 1991), thus research identifying attributes related to preference and naturalness may be the same attributes related to restoration.

Specifically, the low-level visual properties, composed of color and spatial properties, that were significantly related to aesthetic preference and perceived naturalness were as follows: (1) the average hue across all image pixels, (2) the average standard deviation of saturation across all image pixels, (3) the density of straight lines in the image, and (4) the density of non-straight lines in an image (Berman et al., 2014; Kardan et al., 2015). Specifically, participants preferred less average hue (i.e., more yellow-green content rather than blue-purple), more diversity in saturation (i.e., images containing both low and highly saturated colors), less straight edges, and more disorganized (i.e., non-straight) edges, all of which are more common in natural environments (Kardan et al., 2015).

Further, Hunter and Askarinejad (2015) identified 10 different theories used to explain the human preference for nature and benefits of being in natural environments and used these theories to select physical attributes of a scene or image that may influence preference and/or restoration. The physical attributes that Hunter and Askarinejad (2015) identified are higher-level visual features that hold semantic information and were divided into three categories: (1) structure attributes, (2) content attributes, and (3) landscape attributes. They identified 62 attributes in total (for explanation of these attributes, see Hunter and Askarinejad, 2015). Of these 62 attributes, Ibarra and colleagues (2017) identified 10 high-level attributes that were significantly related to preference and perceived naturalness (see Table 2). Interestingly, these significant attributes were all structure or landscape attributes; none of them were content attributes, indicating that the types of nature, water, or even focal points may not be as important as other visual attributes related to structure and landscape.

Attribute	Type of Attribute	Definition
Horizon Line Position	Structure Attribute	The horizon line is "where earth meets sky (seen or inferred position)" (pp.7, Hunter & Askarinejad, 2015). Further, horizon line position is thought to be important for understanding proprioception and visual balance.
Skyline Maximum Undulation	Structure Attribute	"Relates to the maximum amount of vertical shift in the skyline. It is measured as the distance between the highest and lowest points of the skyline and reported as a percentage of the vertical frame height" (pp.12, Hunter & Askarinejad, 2015).
Skyline Vibrancy - Proportion	Structure Attribute	"The proportion of frame width occupied by the canopy-sky interface, the place where foliage vibrancy is most easily measured" (pp.12, Hunter & Askarinejad, 2015).
Skyline Vibrancy -Length	Structure Attribute	"The length of the canopy-sky interface along its path (i.e., includes all vertical shifts). The length is reported as a percent of the frame width and can range from 0% to infinity" (pp.12, Hunter & Askarinejad, 2015).
Vegetation Groundcover	Landscape Attribute	The height of the plants were estimated and compared; vegetation groundcover was defined as "herbaceous plants or low shrubs up to 3 feet tall" (pp.14, Hunter & Askarinejad, 2015).
Non-Veiling Vegetation	Landscape Attribute	"Non-veiling attributes are not covered by any intervening foliage" (pp.14, Hunter & Askarinejad, 2015). Therefore, non-veiling vegetation is the presence of vegetation but in a non-veiling form.
Built Ground Open	Landscape attribute	Built ground involves "any ground surface who materiality has been adjusted by construction such as paved roads or wooden boardwalks" (pp.14, Hunter & Askarinejad, 2015). The open aspect is related to it not being veiled.

Table 2. High-Level Attributes Significantly Related to Preference and Perceived Naturalness (Ibarra et al., 2017)

Importantly, these high-level features mediated the relationship between low-level features and preference and the relationship between low-level features and perceived naturalness (Ibarra et al., 2017). This finding suggests that semantic information in image scenes was highly associated with aesthetic preference and perceived naturalness, and more specifically, the semantic information related to design features. This is important to note as "water" may be significantly associated with preference and naturalness, but according to Ibarra and colleagues (2017), the form of the water and its landscape layout and/or design accounted for more of the variance in the model. Further, understanding design preferences is important for implementing natural elements in urban environments.

However, the aforementioned research is not without limitations. Ibarra et al.'s (2017) model selection strategy for determining which of the 72 low- and high-level features to include in the model has the potential to inflate Type I error significantly. Specifically, Ibarra and colleagues (2017) used stepwise regression with *p*-values of < .05 as their selection criteria. There are several issues with their approach. First, *p*-values as a selection criterion will inflate Type I error. Second, stepwise regression was used to identify potential variables associated with aesthetic preference and naturalness, but then the utilization of these variables in regression and mediation models resulted in biased tests since they are based on the same data. This is also likely to inflate Type I error as the significance of these values should be confirmed using cross-validation methods or with a new sample. Therefore, additional research is necessary to confirm that these low-and high-level variables identified in Ibarra et al. (2017) are of statistical significance.

As such, prior research attempting to identify significant attributes related to aesthetic preference and naturalness should be relevant for identifying attributes related to restorative environments, but this research may have been contaminated with Type I error inflation. Thus, research is needed to determine if these suggested attributes are relevant for designing effective restorative settings, especially as we attempt to make our urban environments more restorative.

Soft Fascination and its Relation to Bottom-Up, Involuntary Attention Capture

If one assumes that some attention resource (e.g., directed attention resource) is being depleted and restored via the light capturing of attention described by soft fascination, how are the features of nature environments facilitating this process? One way to approach this question is to describe what is known to capture attention from work in experimental psychology and determine if there is a plausible correspondence.

The first potential avenue to consider, if one adopts an attention or information-processing focused approach, is the voluntary (directed) versus involuntary attention dissociation as described by Kaplan and Berman (2010). In this perspective, restorative environments work by (1) not requiring voluntary attention in order to navigate, and (2) capturing involuntary attention, while (3) not monopolizing attentional capacity. These three characteristics capture the construct of *soft fascination*. While voluntary or directed attention is primarily not required during more automatic tasks or situations in which multiple tasks must be coordinated, what captures involuntary attention is not as obvious.

The research literature on involuntary attention capture has focused on orienting tasks and visual search tasks, looking at the unique features of a stimulus that affect detection time. The features known to affect search time and arguably capture involuntary attention are visual salience, unique basic features or singletons, abrupt onsets, motion, luminance change, novel objects, and color (Irwin, Colcombe, Kramer, & Hahn, 2000; Ruz & Kupianez, 2002; Yantis & Hillstrom, 1994). However, these paradigms are tested in the context of disrupting or facilitating reaction time performance in orienting attention and performing visual search and may not fit the context of restoration. Most of these attention capturing features may better fit with the concept of *hard fascination,* during which involuntary attention is captured, but attentional capacity is monopolized, requiring directed attention to disengage from the stimuli at hand (Kaplan & Berman, 2010). The exception may be novel stimuli, as the construct of scope has been important in characterizing which environments capture attention long enough for restoration to occur (Kaplan, 1995; 2001).

One interesting and more recent line of research has observed that a task irrelevant stimulus that has been previously paired with a reward was distracting, suggesting that the associated value of a stimulus matters in attention capture (Anderson, Laurent, & Yantis, 2011). Furthermore, stimulus meaning in the form of a happy face has been shown to be more rapidly detected in a rapid attentional detection task (Mack, Pappas, Silverman, & Gay, 2002). Taken together, one could hypothesize that higher value, meaningful stimuli associated with positive affect may be more attention capturing than at least neutral stimuli. When there are no threatening stimuli present, which would otherwise capture attention powerfully (Mathews, Mackintosh, & Fulcher, 1997), the presence of higher value, positive, and meaningful stimuli may play a role in attention capture, less directed attention, and provide a correspondence with the features of nature environments. Indeed, recent research focusing on gaze behavior found longer gaze times for nature stimuli compared to artificial stimuli when presented at the same time (Masuch, Einenkel, Weninger, Schwarzl, Girsovics, & Oberzaucher, 2018), and high fascination scenes engender more fixations and eye movements relative to low fascination environments (Berto, Massaccesi, & Pasini, 2008), suggesting less effort and more attention capture.

An alternative and potentially complementary set of features that may be associated with fascinating environments are visual complexity and fractal geometry (Aks & Sprott, 1996; Van den Berg, Joye, & Koole, 2016). Environments and scenes with a high number of visual elements are thought to be visually complex. Furthermore, if the visual elements and their interrelationships can be characterized by significant reoccurrence or repetition of these visual elements over different scales, the scene is said to be relatively high in fractal geometry. Aks and Sprott (1996) demonstrated that their sample of participants preferred generated objects with a fractal dimension averaged 1.26 and a Lyapunov exponent averaged 0.37 bits per iteration, which is consistent with natural scenes. Van der Berg and colleagues (2016) demonstrated that nature scenes have higher levels of fascination, perceived restorativeness, and visual complexity than built scenes, and that this effect was statistically mediated by the higher subjectively reported visual complexity of the scenes when magnetified at different scales. This means the reported fascination and length of viewing time (a behavioral measure of fascination) is at least partially governed by visual complexity. Therefore, it would be reasonable to not only consider singular features (e.g., novelty, value, positive affect) but also how the elements of a scene are interrelated (e.g., complexity and fractal geometry) when considering how to design built environments with high potential for soft fascination. However, this does not necessarily imply that even higher levels of visual complexity would lead to more soft fascination. There may be a fine distinction between scenes that are either too simple, just complex enough, or incomprehensible.

Finally, we should note that the previous discussion on visual components that elicit soft fascination focuses on soft fascination as *content*, which is initiated by a stimulus or set of stimuli that does not monopolize attentional capacity, and this engagement initiated by soft fascination content is sustained over time. Other approaches to operationalize or more carefully define soft fascination may emphasize soft fascination as a *process*, such as story-telling or some other mode of mental approach that acts to sustain engagement or interest (Berto, 2011). Resolving the overlap between these alternative interpretations of soft fascination is an interesting problem for those intending to best make use of restorative environments.

Directed Attention Depletion: An Information Processing Framework

In addition to unclear operational definitions of the characteristics thought to make an environment restorative, particularly the fundamental characteristic of soft fascination, more empirical evidence is needed to support the mechanism proposed by ART; that is, that nature innately grabs bottom-up attention, and this allows top-down attention to recuperate or replenish. This has practical implications for establishing the types of mental fatigue that is best suited for an intervention with restorative elements. The previous section addressed the aspect of this mechanism that assumes involuntary attention is being facilitated by a soft fascination characteristic in an environment. Literature on information processing and resource theory may provide an updated perspective to the proposed underlying mechanism of ART, which is heavily centered on the concepts of voluntary and involuntary attention that were defined by William James (1892) over a century ago. While we acknowledge that William James' contribution to psychology is unparalled, we decided to link these concepts to current tenants of cognitive and human factors psychology to address more recent conceptualizations.

Directed Attention in ART: Unitary or Multiple Information Processing Resources?

Information processing theory and cognitive psychology more broadly can be characterized by a few general principles or assumptions insofar as the question of nature is concerned: limited mental capacity, a required control or executive mechanism for the processing of information (e.g., storage and retrieval), a two-way flow of information from the senses (bottom-up) and memory (top-town) that guides behavior, and a genetic predisposition to process certain types of information in specific fashions (e.g., perception of faces, local language learning; Anderson, 2005). These information processing assumptions also apply specifically to attentional processes (Schiffrin & Schneider, 1977). One theory of cognition that has been specifically linked to nature and attentional processes, is resource theory (Berto, 2005). Resource theory focuses on the assumption of limited mental capacity in cognitive processing and posits a resource pool as an organizing metaphor for thinking about attention and mental effort (Warm, Parasuraman, & Matthews, 2008). Attentional tasks requiring mental effort will deplete this resource pool, and when there is no more availability of the resource, task performance will worsen, and fatigue will occur (Warm et al., 2008). Originally, attentional capacity was construed as a single mental resource pool (Kahneman, 1973), but more recent research has conceptualized attention as comprising multiple resources (Wickens, 2002), such as separate pools for visual and auditory processing.

Directed attention, representing the aforementioned assumption that there is a control mechanism that directs the processing of information (in this context, attention), has also been thought to have its own separate resource pool (Just, Carpenter, & Miyake, 2003). When individuals exert continuous effort to direct attention to activities in daily life and the workplace, this directed attention resource pool will deplete, resulting in fatigue and diminished performance on directed attention tasks. Nature then presents an environment in which this directed attention resource pool can more rapidly replenish (Berto, 2005; Kaplan & Berman, 2010).

Taking a more information processing approach, Kaplan (1995; 2001) proposed that when navigating complex situations involving more than one domain of knowledge, individuals must manage multiple mental structures and perception/action relationships that conflict with each other. This management requires intervention by the directed attention mechanism to inhibit certain mental structures in order to behave or perform appropriately over the course of a complex task. Furthermore, even performance in a well-learned single domain with an associated mental structure, which is initially fairly automatic, will eventually fatigue and require intervention by directed attention (Kaplan, 2001). Nature provides an environmental intervention by avoiding the activation of fatigued mental structures (being away), and avoiding any allocation of effort by directed attention over an extended period of time (soft fascination, extent, and goal compatibility).

While ART has assumed to encompass many domains that rely on executive attention (Kaplan & Berman, 2010), the unity of a single directed or executive attention construct has been challenged. Brain imaging research looking at attention networks has noted significant support for at least two separate directed attention networks, a frontoparietal system which corresponds to task-switching and task initiation, and a cingulo-opercular system that performs error monitoring and task maintenance over time (Petersen & Posner, 2012). As a side note, Kaplan and Berman (2010) has suggested the cingulo-opercular system as a candidate for the neural substrate for directed attention in ART. Secondly, factor analytic research has disassociated executive functioning performance into (1) a shared or common executive functioning ability, (2) an updating component (e.g., working memory), and (3) a task set shifting component (Miyake & Friedman, 2012).

Measuring the Construct of Directed Attention

A related gap in ART is the lack of specificity in defining depletion of directed attention resources. As can be expected, if there is uncertainty if directed attention is a unitary or multiple resource, then these different perspectives of directed attention will impact how it is being measured. ART claims that directed attention resources are being depleted and subsequently recovered, but a broad scope of cognitive tasks have been used to demonstrate this effect, such as tasks typically used to measure selective attention, sustained attention, working memory, and higher-order executive functioning (Berman, Jonides, & Kaplan, 2008; Berto, 2005; Hartig, Evans, Jamner, Davis, & Gärling, 2003; Kaplan, 1995; Kaplan & Berman, 2010; Laumann, Gärling, & Stormark, 2003; Ohly et al., 2016; Shin, Shin, Yeoun, & Kim, 2011).

Further, meta-analytic research by Ohly and colleagues (2016), which reviewed attention restoration across a great variety of cognitive tasks domains, only observed nature benefits for three tasks: Digit Span Forward, Digit Span Backward, and Trail Making Test B. These tasks were interpreted as posing demands onto working memory. More recent meta-analyses have implicated certain working memory and cognitive flexibility tasks in restorative environments (Stevenson, Schilhab, & Bentsen, 2018). While working memory is closely related to attentional processes, including directed attention, the linkage between them in the context of ART is unclear. Further, it is too simplistic to attribute the restorative effect to the replenishment of working memory resources, specifically. Other tasks that also pose high working memory loads, like the Symbol Digits Modality Test, did not benefit from nature interventions (Ohly et al., 2016). Further, among those tasks that were identified to benefit from nature interventions, the effectiveness of the restorative effect was not directly linked to working memory load. For example, the Digit Span Forward and Digit Span Backward tasks showed comparable effectiveness of nature interventions, even though the Digits Span Backward tests places greater demands onto working memory (Ohly et al., 2016). Thus, it is presently unclear if directed attention or a type of directed attention is the actual cognitive resource being depleted and subsequently recovered in the restorative effect, as ART suggests, or if the restorative effect is more complex and impacting several cognitive processes that are interrelated.

Beyond the issue that it is not known which specific directed attention resources recuperate under nature exposure, ART's underlying assumption that nature interventions result in recuperation of fatigued attentional resources has received limited testing (Joye & Dewitte, 2018). Specifically, most ART studies follow a pre-post experimental design. In such a design, participants perform a cognitively demanding task or set of tasks (pre-nature exposure). Then, they are exposed to nature or urban (serving as a control) environments either directly (e.g., walking on a nature trail or city sidewalk) or indirectly (e.g., viewing digital nature or urban images). Finally, participants perform the same cognitively demanding task or set of tasks (post-nature exposure). While the pre-nature exposure task or set of tasks is intended to deplete participants of their directed attention resources, to our knowledge, prior research has not tested if restoration can occur at varying levels of depletion due to different task loads. As Kaplan and Berman (2010) argued, tasks of attention rarely require only involuntary attention or only voluntary/directed attention. Instead, attention tasks likely require varying amounts of effort. Thus, it is presently unknown if people can profit from the restorative effect in states of higher directed attention capacity (i.e., a lower effort/depletion state). If performance improvement occurs in individuals whose attentional resources have not been taxed, the beneficial performance effects associated with nature may not be caused by attention restoration as proposed by ART.

Future Directions

The purpose of this paper is to integrate literature from multiple subdisciplines with the hopes of inspiring future research that can aid in filling the gaps presented by prior literature on ART. We believe this paper presents opportunity for the following future directions:

- *What are the characteristics of an environment that make it restorative?* This is an imperative research question for those wanting to apply ART to design and operational settings. The four characteristics presented by Kaplan (1995) are not operationally defined well, easy to measure, and thus, implement. Further, the aesthetics and environmental preference literature that seemed to inspire ART is equally vague in terms of defining and measuring variables of interest. However, more recent research has integrated perceptual and landscape design variables to aid in better understanding aspects of nature that are associated with preference. Since preference for an environment is related to restoration, these variables may be informative for promoting cognitive and emotional restoration. However, there are limitations to this recent research, as it was correlational in nature. Therefore, future research could experimentally manipulate these visual variables thought to be correlated with environmental preference to determine if they impact restoration.
- *What is soft fascination, and how does it operate?* This research question may be of most interest to an audience who focuses on theoretical implications. If soft fascination has the three characteristics described

(1) does not require voluntary attention, (2) captures involuntary attention, (3) does not monopolize attentional capacity, how does this relate to observable behavior? One type of proposed behavior thought to be linked with soft fascination is gaze behavior, such as more fixations and eye movements for scenes with higher fascination (Berto, Massaccesi, & Pasini, 2008). Why does this occur, and what is/are the mechanism(s)? If these are known, then we could explain and predict more about what scenes and features engender soft fascination.

- *What stimuli elicit soft fascination?* This research question may be of most interest to an audience who focuses on applied research, specifically the application of ART to rapidly relieve mental fatigue. There are two potential methods to better understanding soft fascination and the attributes in an environment that elicit soft fascination: (1) A brute force approach; that is, develop object/scene/feature inventories that have been sorted with scales that measure soft fascination (e.g., Perceived Restorativeness Scale; Hartig, Korpela, Evans, & Garling, 1997), and (2) Besides nature, consider candidate features proposed here based on the information processing literature review, specifically positive stimuli with relatively higher value/meaning and fractal geometries. Further, certain aesthetic variables described in this paper may aid in promoting soft fascination and other aspects of restorativeness and should be considered.
- *What is directed attention, and does directed attention capacity need to be full depleted for restoration via nature to occur?* This research question has important theoretical and practical implications. Theoretically, if restoration can improve other cognitive processes beyond directed attention or occur after varying levels of directed attention depletion, then ART may need to be modified or expanded to encompass modern empirical findings. Researchers should operationally define directed attention and use this definition to better inform the tasks being used to measure restoration. Further, validating that directed attention is being depleted by the task(s) and a control condition in which directed attention is being less depleted or not depleted is needed. This would then allow for better scoping tools for designers, so that they can consider whether people within the environment would benefit from implementing restorative components, given their prior degree and type of directed attention depletion.

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