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DECODING RESTORATIVENESS: EXPLORING THE VISUAL AND PERCEPTUAL FOUNDATIONS OF ENVIRONMENTAL RESTORATIVENESS THROUGH A PSYCHOPHYSICAL APPROACH

ABSTRACT

This doctoral dissertation combines the existing knowledge from perceptual psychology and environmental psychology to explore the mechanisms underlying the construct of restorativeness (REST; i.e., the capacity of physical spaces to promote resource recovery for individuals), with a particular focus on identifying the basic visual components of a space that elicit restorative perceptions. Specifically, the research sought to clarify which elementary features of visual stimuli (BVFs) contribute to the global perceptual properties (BGPs) of natural scenes and how these, in turn, foster the sense of restorativeness. By integrating a psychophysical approach with Gestalt principles of perceptual organization, this dissertation aimed to bridge the gap between theoretical accounts of restoration and empirical evidence on visual processing.

Restorativeness is a central construct in environmental psychology, referring to the capacity of certain environments - particularly those rich in natural elements - to promote the recovery of depleted emotional and cognitive resources (Hartig, 2004). A large body of research has shown that restorative environments enhance positive emotions and reduce stress (Mattila et al., 2020; Martinez-Soto et al., 2021; Sharam et al., 2022; Gentile et al., 2023), improve attention, concentration, and decision-making (Amicone et al., 2018; Aristizabal et al., 2021; Kimura et al., 2021), and even facilitate recovery in individuals with psychological disorders such as anxiety and depression (Meuwese et al., 2021; Stigsdotter & Grahn, 2003). These benefits have been observed through both subjective measures (e.g., self-report scales) and objective physiological indicators (e.g., heart rate, cortisol levels), highlighting the relevance of restorativeness for human health and well-being.

The theoretical framework of this work combines well-established psychological models of restoration with perceptual theories. Attention Restoration Theory (ART; Kaplan & Kaplan, 1989) provided the conceptual basis for understanding how natural environments promote recovery of depleted attentional resources through "soft fascination." Complementary approaches, such as the Scene-Centered Approach (SCA; Oliva & Torralba, 2006) and Feature Integration Theory (Treisman & Gelade, 1980), explained how early attentive bottom-up processes and global scene properties guide visual perception. Gestalt principles of perceptual organization further informed the assumption that restorativeness emerges from the aggregation of basic perceptual items into coherent global configurations. This integration allowed us to investigate restorativeness not only as a psychological construct, but also as the emergent outcome of visuo-perceptual mechanisms.

Three studies were conducted to test these assumptions. The first contribution was a narrative review of psychophysical literature examining how bottom-up attention is captured by basic visual features of a stimulating visual configuration (i.e., an image), such as color, luminance, orientation, and closure. The review confirmed that these features and their gestalt-like relationships (e.g., proximity, symmetry, collinearity) activate pre-attentive grouping mechanisms, facilitating

rapid scene segmentation and the emergence of perceptual “proto-objects.” This evidence supports the hypothesis that automatic attentional processes, central to ART, are grounded in low-level visual features. The second study empirically examined the role of Basic Global Properties (BGPs) of a scene - openness, expansion, depth, transience, and navigability - in predicting perceived restorativeness. Using both Likert scales and pairwise comparison methods on natural images, results showed that BGPs significantly predicted the four classical dimensions of REST (i.e., fascination, being away, coherence, scope). Moreover, interaction effects between structural (e.g., openness, expansion) and functional (e.g., transience, navigability) properties were observed, highlighting the combined contribution of multiple BGPs to restorative perception. The third study integrated ART, SCA, and Gestalt principles in a two-part experimental design. In Study 1, participants evaluated natural images on eight basic visual features (BVFs), which cluster analyses grouped into meaningful constructs corresponding to BGPs. In Study 2, image clusters derived from BVFs were tested as predictors of perceived restorativeness using mixed linear models. Results showed that clusters that differed in the presence of BGPs predicted different levels of perceived restorativeness. In particular, clusters characterized by higher levels of complexity, openness, and expansion elicited stronger perceptions of restorativeness and fascination compared to clusters dominated by texture features.

Overall, the findings of this doctoral work indicate that restorativeness is not an inherent property of natural environments, but rather an emergent perceptual response shaped by the organization of basic visual features into global properties that attract involuntary attention. By identifying these perceptual “ingredients”, the project provides both theoretical advances in understanding restoration processes and practical implications for the design of human-made environments that foster psychological well-being.

INTRODUCTION

The Construct of Restorativeness in Environmental Psychology and Its Beneficial Effects on Humans

This study adopts a psychophysical approach to identify which specific visual elements in physical environments - or their representations - elicit a perception of restorativeness, aiming to clarify the underlying mechanisms of visual perception. In recent decades, the concept of restorativeness related to physical places has undergone significant development, not only within Environmental Psychology where it originated, but also in other fields such as Sport Psychology and Health Psychology. Hartig (2004) defines restorative environments capable of facilitating the recovery of emotional and cognitive resources, thereby enhancing well-being and resilience to stressful events.

A large body of literature has demonstrated that humans living, studying, working, and generally spending time in restorative places have multiple beneficial effects that can be summarized as follows:

- Enhancement of emotional responses. Exposure to restorative environments increases positive emotions, such as a sense of tranquility, calm, and joy while reducing negative affective states, such as tension, anger, and hostility (Ulrich, 1983; Ruso & Atzwanger, 2003; Biederman & Vessel, 2006; Karmanov & Hamel, 2008; White, Smith, Humphryes et al., 2010; Barton & Pretty, 2010; Mattila et al., 2020; Martinez-Soto et al., 2021; Sharam et al., 2022; Gentile et al., 2023);
- Enhancement of cognitive responses. It has been shown that exposure to restorative environments/images provides benefits across various areas of cognitive functioning. Specifically, the following improvements have been observed:
    - enhancement of mental engagement and concentration (Biederman & Vessel, 2006; Amicone et al., 2018; Aristizabal et al., 2021; Kimura et al., 2021);
    - improvement in decision-making processes (Sun, Soh & Xu, 2022);
    - enhancement of attentional functions and memory restoration (Ulrich, Simons, Losito et al., 1991; Petherick, 2000; Wang & Taylor, 2006; Berto et al., 2010; Grahn & Stigsdotter, 2010; Lin, Tsai, Sullivan, Chang & Chang, 2014; Amicone et al., 2018; Spano et al., 2023);

    - improvement in executive functioning and working memory (Alvarsson et al., 2010; Bauman et al., 2023; Ojala et al., 2023);

- Improved ability to cope with stressful events. The reduction of stress levels following contact with restorative environments/images has been confirmed by self-report instruments (Pasini et al., 2021; Martinez-Soto, 2021; Lee et al., 2022; Spano et al., 2022) and also through the measurement of physiological parameters such as:
    - heart rate and blood pressure (Brown, Barton & Gladwell, 2013; van den Berg, Hartig, & Staats, 2007; Tsunetsugu & Miyazaki, 2005; Biederman & Vessel, 2006);
    - hormonal response (Calogiuri, Evensen, Weydahl, Andersson, Patil, Ihlebæk & Raanaas, 2015; Park, Tsunetsugu, Kasetani et al., 2009; Orsega-Smith, Mowen, Payne et al., 2004; Hartig, Evans, Jamner et al., 2003; Ulrich, Simons, Losito et al., 1991);
    - sympathetic nervous system response (Li, 2010; Park, Tsunetsugu, Ishii et al., 2008; Beauchamp et al., 2003; Ulrich, Simons, Losito et al., 1991);
- Improvement of mental conditions in individuals with psychopathologies (e.g., chronic anxiety, major depression; Otis et al., 2024; Fruehauf, Niedermeier, Elliott, Ledochowski, Marksteiner & Kopp, 2016; Li, Kobayashi, Inagaki et al., 2012; Tsunetsugu, Park, & Miyazaki, 2010; Kim, Ren, & Fielding, 2007; Meuwese, Dijkstra, Maas & Koole, 2021; Stigsdotter & Grahn, 2003).

Given this body of evidence, deepening our understanding of the mechanisms that generate the perception of restorativeness and identifying the specific elements in physical environments capable of activating such mechanisms is considered valuable not only for advancing basic research but also for providing useful guidelines for professionals involved in environmental design.

Main Theories Underpinning the Construct of Restorativeness

Several theories have been proposed to explain the beneficial effect that humans experience when exposed to restorative environments or images. The Biophilia Hypothesis (Wilson, 1984) addresses this phenomenon from an evolutionary perspective. From a phylogenetic standpoint, since the human species evolved in natural environments, contact with natural elements representing useful survival resources elicits a sense of comfort and safety. In fact, in nature there are water to drink, trees for shelter, bushes for gathering fruits, and other valuable natural elements for survival. According to this theory, the key mechanism underlying restorativeness is the biological attraction humans feel toward natural settings and natural elements as sources of life. The sense of restorativeness would thus be an innate, automatic, and positive response triggered by the exposure to such environments.

Similarly, the Savanna Hypothesis (Orians, 1980) explains the restorative response through evolutionary factors. According to this theory, human beings prefer landscapes that resemble the African savanna, the environment in which early hominids evolved. Environments with typical savanna features (e.g., wide open views, presence of water, scattered trees with broad canopies) are perceived attractive and safe - and thus restorative - because they respond to primordial survival needs (e.g., exploration, shelter, access to resources). In this case, as well, the sense of restorativeness is the outcome of an automatic and affective (pre-cognitive) preference response activated by contact with natural landscapes. This contact facilitates the emergence of positive emotions (e.g., calmness, tranquility, interest) and contributes to psychological well-being.

The Stress Recovery Theory (SRT; Ulrich, 1983) aligns with the previously mentioned theories. The central idea is that exposure to natural landscapes and elements facilitates recovery from physiological and psychological stress. Also grounded in evolutionary assumptions, this theory posits that contact with natural settings - more so than with built environments - reduces the activation of the sympathetic nervous system, lowers blood pressure, heart rate, and cortisol levels, and leads to a state of relaxation and restoration. In this framework, the sense of restorativeness is linked to immediate relief from negative emotions and heightened arousal.

The Attention Restoration Theory (ART; Kaplan & Kaplan, 1989) aims to explore the perceptual processes triggered by contact with natural environments or images. The core hypothesis is that natural environments help restore directed attention, which can become depleted through prolonged use. Natural scenes possess features that gently and softly capture attention, generating involuntary fascination that allows voluntary attention to recover. According to ART, the experience of restorativeness stems from the perceptual ease with which the visual system processes natural elements. These elements are capable of attracting attention in an automatic yet non-coercive way, facilitating the understanding of the environment in which the individual is situated and signaling the environment is beneficial for the individual.

Finally, the Perceptual Fluency Account (Joye & van den Berg, 2011) posits that natural environments or images are restorative because they are perceived more fluently and effortlessly, due to the visual elements that constitute their structure. The sense of restorativeness is postulated as the result of the ease with which the perceptual system processes natural patterns and forms (such as natural textures, the presence of fractals, or smooth curves). This perceptual fluency produces a positive sensation and a sense of well-being, thereby contributing to the cognitive and emotional regeneration of the individual.

Taken together, these theories suggest that:

a) environments/images containing natural elements, compared to human-made environments, promote a greater sense of restorativeness (i.e., the perception of recovery of cognitive and emotional resources);
b) the perception of restorativeness is the result of pre-cognitive mechanisms (primarily emotional in SRT, and perceptual in ART) that are activated through contact with natural environments/images with specific characteristics;
c) c) natural environments/images contain elements or features capable of facilitating the perceptual processing of a scene, allowing the individual to quickly understand where they are and signaling that the environment constitutes a resource and does not contain potential risks or threats.

Although the aforementioned theories provide valuable insights into the mechanisms underlying the sense of restorativeness, they do not offer a detailed description of which specific elements, within a natural environment or image, can foster restorativeness perception. This work attempts to connect theories of restorativeness - in particular the Attention Restoration Theory (ART; Kaplan & Kaplan, 1989) - to those that explain visual perceptual processes from a Gestalt perspective, in order to better understand the relationship between restorativeness and certain basic visual features of the images which, according to perceptual theories derived from Gestalt psychology (i.e., Feature Integration Theory, FIT; Treisman & Gelade, 1980; Scene-Centered Approach, SCA; Oliva & Torralba, 2006), contribute to providing the observer with a rapid, global, and immediate representation of the environment/image he or she is facing with.

It is hypothesized that within an image - conceptualized as a visually stimulating configuration - basic Gestalt-derived elements exist (e.g., proximity of visual items, collinearity, symmetry, closure, continuity of lines) that, when aggregated in various configurations and providing the observer with quick information about the type of environment they are facing, may facilitate or hinder the perceptual processes related to restorativeness. Understanding which basic elements of an environment/image promote restorativeness and which, on the contrary, hinder it, will not only contribute to advancing theoretical knowledge of the perceptual mechanisms associated with the construct of restorativeness, but may also offer valuable insights for practitioners (e.g., designers, architects, interior decorators) involved in the creation of a wide variety of human-inhabited spaces (e.g., domestic, educational, work-related, leisure) that support well-being and psychological restoration.

Connection between Attention Restoration Theory and Gestalt Theories of Visual Perception

Attention Restoration Theory (ART; Kaplan & Kaplan, 1989) is among the most widely accepted theories for explaining the regenerative effect that contact with natural images/environments has on humans. According to ART, natural environments, compared to built environments, possess properties that generate "soft fascination" in humans; that is, they elicit an attraction of visual attention in an automatic, yet non-coercive, manner. In other words, when a subject observes a natural landscape, his or her visual attention is captured and guided by certain overall properties of the image, this "soft capture" of attention, which operates automatically and without conscious intentionality, allows the recovery of the directing processes of voluntary and conscious (i.e., with effort) visual attention and hence the sense of restorativeness experienced by the subject.

ART has identified five overall characteristics that natural images, in comparison with scenes of urban and built environments, possess that are responsible for the perception of restorativeness. A natural environment, to be restorative, must have:

- Fascination. The capacity of one place to arouse interest and a sense of aesthetic pleasantness. A fascinating environment is composed of a combination of features that capture attention and prompt the subject to contemplation. A fascinating environment is capable of arousing wonder, i.e., a feeling of surprise mixed with admiration that is experienced in the presence of something unexpected, extraordinary, and judged to be very beautiful.

- Being Away. The extent to which a place allows the subject to range with the imagination and feel far away from everyday life. Such an environment possesses unusual features because of the way they are placed or combined. They are capable of activating imaginative processes that allow subjects to momentarily break away from the routine of daily activities. In short, these environments allow subjects to "take a break" from routine and recurring situations;
- Coherence. This dimension pertains to the perceptual and conceptual structuring of the parts that compose the environment. It is the extent to which elements are perceived as an ordered whole. The environmental features are detected as orderly, harmonious, and coherent for the context. The elements are combined in a way that makes sense, they are also functional for the activities one must perform in the environment;
- Scope. It refers to how the areas surrounding the scene, and also the parts that are not seen but imagined, are considered explorable. Environments with high scope are places with no barriers, that invite to explore, going farther, moved by curiosity to discover what lies beyond the visible part of the scene. These are easily accessible places with no obstacles in the ground and no threatening aspects (e.g., dark or dimly lit spots) that might signal dangers;
- Compatibility. An environment has a high level of compatibility when there is a high correspondence between the physical characteristics of the environment and the subject's intended idea of actions or movements in that environment. For example, if I intend to relax by reading a book, a natural environment where I can sit sheltered, free of distractors, and simultaneously quiet has a high level of compatibility with respect to my purpose.

It is important to clarify that ART does not claim all natural environments are restorative (think, for example, on a stormy sea, which is not really a regenerative vision), nor that built environments lack restorative potential. Rather, it suggests that, on average, natural settings tend to score higher on key restorative dimensions. Indeed, research on the topic has shown that natural places are typically associated with higher levels in the restorativeness sub-dimensions, compared to built environments (Gentile et al., 2023; Nikunen et al, 2014; Pals et al, 2014;), but some human-built places (e.g., villages with artistic content, squares with high architectural value, and the night skylines of cities) are perceived as restorative as natural environments (Lee et al., 2022; Menardo et al., 2021; Scopelliti et al., 2019; White et al., 2010).

Supported by empirical evidence, this work argues that nature is not restorative per se but because of certain global properties that natural scenes generally incorporate. If we can bring these global properties into human-made environments, they can generate a restorative effect too. For this reason is important to understand which elements of an image/environment contribute to the sense of fascination, being away, coherence, scope, and compatibility, these being precisely global, emergent dimensions of the image. In this work is assumed that these global restorative properties are generated by a specific combination of basic elements of the stimulating visual configuration that the visual system is able to grasp and organize, so that images acquire meaning.

As early as the 1920s, the authors who founded Gestalt Psychology - and who first studied how human vision works when brought in contact with simple physical items - understood that the conscious image is a "whole" resulting from precise rules of aggregation of elementary parts of the stimulating visual configuration. According to Gestalt thought (Wertheimer, 1923; Koffka, 1935; Rubin, 1921; Sekuler and Bennett, 2001; Lee and Blake, 1999; Beck and Palmer, 2002; Palmer and Beck, 2007; Wagemans, Feldman, Gepshtein, Kimchi, Pomerantz, Van der Helm and Van Leeuwen, 2012) there are two fundamental processes of perceptual organization:

1. grouping, according to which the visual system groups physical items on the basis of specific relationships between them (e.g., proximity, similarity, continuity of direction, common orientation in space, closure, structural coherence, and restless articulation);
2. figure-background articulation, according to which the human visual system divides the percept into figures (i.e, compact elements, with objective character, capable of attracting attention) and background (i.e., indefinite space) trusting on relationships between physical items (e.g., the smaller area, included in larger areas, with convex edges, whose axes tend to coincide with the vertical or horizontal axes of space is perceived as a figure).

From Gestalt studies derive some more recent theories explaining the role that human visual attention plays in the processes of grouping visual stimuli and in creating segmentation between the figures and the background. Among the theories, particularly interesting for this research work is the Feature Integration Theory (FIT; Treisman and Gelade, 1980). FIT hypothesizes a perceptual pathway including automatic attention through which the visual information is processed and integrated to generate a conscious image. According to this theory, visual perception proceeds through two distinct but complementary stages. In the first phase - termed pre-attentive phase - the visual system through bottom-up attentional processes automatically and in parallel extracts some simple features, such as basic shapes, orientation in space, and size ratios of visual items. This first stage is intended to provide the subject with a coarse representation of how the space in which he or she is located is configured (e.g., figuring out whether he or she is in a wide and open or closed and narrow space). Follows a second phase of visual perception - called the attentional phase - in which integration mechanisms operate to arrive at a conscious and detailed view of the image. In this second phase, after the subject has constructed a global idea of space, attention is directed to a specific area of the visual field and, at this point, different features of the space are attentively attended to. By this process, the subject arrives at a coherent and conscious representation of the perceived scene.

For this work, it is interesting to dwell on the pre-attentional stage of visual perception postulated by FIT, according to which certain basic stimuli of the physical domain can capture attention automatically and involuntarily, thus the process of perceptual construction and the subsequent directing of attentional focus is facilitated. FIT provides a non-exhaustive list of basic items attracting attention automatically in the pre-attentive phase, it includes: the color of items and the contrast of color and brightness between items, the orientation in space of the line segments constituting the spatial planes (i.e., vertical, horizontal, and oblique), the intersection between segments, the ending of lines (e.g., curved or pointed lines), the frequency with certain basic items recur, the size and size contrasts between items. While FIT has the merit of having identified some basic features that attract attention through bottom-up processes, it does not go on to explain how these features combine to create different visual configurations (e.g., open vs. closed spaces).

One theory representing a recent evolution of FIT is the Scene Centered Approach (SCA; Torralba and Oliva, 2006). According to the SCA, when the human eye encounters a new environment that needs to be decoded, it first gets a global idea of the kind of space the subject is in. In line with FIT, the SCA postulates that we first create an overall representation of the environment and then we go on, focusing attention on specific elements of it. According to the SCA, at an early stage of vision, the perceptual system tries to arrive at a rough representation of some basic and global features of the environment. They concern: the structure of the space (encompassing the dimensions of openness, expansion, and depth), the rapidity of changes that will occur in the environment through the course of time (encompassing the dimensions of transience and temperature), and the possibilities of action within in the space (encompassing the dimensions of concealment and navigability). These dimensions considered fundamental to the SCA, and their function for the rapid representation of the environment in which the subject is located are briefly described below:

- Openness. It indicates how wide the scene is, i.e., there is the possibility to range the gaze to all sides of the image or, on the contrary, how closed the scene is, i.e., there are natural (e.g., stones) or built elements (e.g., objects) that limit the view;
- Expansion. It provides a sense of perspective of the scene. It ranges from very flat scenes, with a single horizontal line delimiting the horizon, to scenes with many parallel lines converging at a single point, with the function of vanishing point;
- Depth: It provides the sense of depth of the scene. It ranges from shallow scenes, in which the elements are depicted on a single plane (e.g., in the foreground), to scenes in which the elements are depicted in various scales of size, providing a sense of high depth;
- Transience. It concerns how much the image, from one glance to the next, can change. It ranges from scenes with a broad sense of movement (e.g., if streams or falling leaves are present) to static images, which can change only over geological eras (e.g., stones);
- Temperature. It provides an idea of the temperature level of the environment. It is possible to have environments that appear cool, with color gradations involving shades of blue, green (e.g., teal or sage green), purple (especially lilac, and lavender), and turquoise. Conversely, it is possible to be in the presence of environments that appear warm, comprising mainly colors such as red, orange, yellow, or earthy tones (e.g., ochre, terracotta, rust) or even ivory, cream, warm brown;
- Concealment. It concerns the possibilities that the scene offers for hiding among the elements of the environment. It goes from scenes in which the subject is completely exposed (e.g., a desert) to scenes in which natural elements offer the possibility of hiding and refuge (e.g., trees, rocks);
- Navigability. It refers to how freely the subject can move in the environment. It varies from scenes in which movement is greatly restricted (e.g., for the presence of boulders) to scenes in which the subject can move in any direction (e.g., a field of flowers).

The dimensions described above are defined by Torralba and Oliva's (2006) Basic Global Properties (BGPs) of the environment. According to the authors, humans rely on these dimensions when they need to quickly interpret the characteristics of the space in which they are. Moreover, in the distinction between urban and natural environments, the latter generally exhibit higher levels of BGPs. The theory implies that BGPs derive from the aggregation of basic features of the physical environment (e.g., colors, shapes, line orientation in the space) but does not specify which basic features concur in the determination of each BGPs.

Given the above, this work seeks to better understand the role of some basic features of physical stimuli in determining the basic global properties (BGPs) of the environment/image and the relationship between them and the perception of restorativeness associated with an environment/image. Indeed, by aggregating the theories described above, namely:

- agreeing with ART, the sense of restorativeness elicited by an environment/image is the consequence of a process of "soft fascination," i.e., an automatic attraction of attention by certain overall features of the environment/image (i.e., fascination, being away, coherence, scope, compatibility), and these dimensions are more pronounced in natural environments than in built ones;
- agreeing with the SCA, when the human visual perceptual system needs to quickly distinguish between natural and built environments/images it relies on some basic global properties of the image (i.e., BGPs: openness, expansion, depth, transience, temperature, concealment, navigability) that give a raw but overall representation of the scene;
- Concurring with FIT, for the creation of a raw but overall representation of an environment/image, at an early stage of vision, visual attention automatically, effortlessly, and in parallel extracts some basic stimuli from the physical world (e.g., color, brightness, orientation in the space of lines, items segmentation and closure) that are then aggregated together to generate gestalt form and the distinction between figures and background;

it is possible to hypothesize that there is a relationship between some basic items of the physical world, the basic global properties (BGPs) of an environment/image, and the perceived restorativeness associated with that environment/image. The function of this contribution is to test whether some basic features of the physical world, by attracting automatic attention through bottom-up processes and aggregating together into basic global properties (BGPs) of the environment/image, contribute to generating the sense of soft fascination associated to the dimensions that make up the construct of restorativeness (i.e., fascination, being away, coherence, scope, compatibility). In this work, drawing on a gestalt-derived conception of perception, the dimensions that make up the construct of restorativeness are considered "emergent properties" (cf. Paolo Bozzi, 1990) of the environment/image, which do not exist in themselves but are the result of particular combinations of basic visual items existing in the physical world. Indeed, if we come to understand how basic pre-attentive stimuli combine with each other, resulting in different spatial configurations associated with distinct levels of restorativeness, we have found the basic ingredients of restorativeness itself. These ingredients can be reproduced in human-built environments to design living, studying, and working spaces that foster not only the physical but also the psychological well-being of the people who inhabit them.

Methods of measuring the basic features of an environment/image

Turning to the topic of measuring the dimensions of interest in the present work, while several validated scales exist for the construct of restorativeness, there are no specific scales for measuring the BGPs of an image identified by the SCA (i.e., openness, expansion, depth, transience, temperature, concealment, navigability) nor specific scales for the basic features assumed to underlie the BGPs (e.g., shape, color, orientation in space, and ratios of visual items). In addition, because the basic features are embedded in the image, identifying the BGPs of a scene can represent a difficult task, especially for individuals who do not have specific drawing or architectural skills. An example can clarify this concept. The BGP "expansion" characterizes images whose spatial configuration consists of two main lines that start out separate and gradually join at a single point, creating a vanishing point toward which the viewer's gaze is immediately drawn. This spatial configuration lends depth to the image and gives the impression that one can see quite a bit far into the scene. People who have no notions of how linear perspective is constructed on a two-dimensional plane will struggle to detect the presence of the expansion dimension and, more importantly, will struggle to assign higher or lower expansion scores to different images relying on the presence of a clear vanishing point. For these reasons, in this work was necessary to think of a measurement method facilitating subjects in the task of evaluating the BGPs of an environment/image. The pairwise comparison method (Thurstone, 1927; Torgerson, 1958) was considered a suitable measurement method in order to reach the purpose of this research.

The pairwise comparison method is a psychometric scaling technique for ordering a set of stimuli (in the case of this research, images of natural environments) along a latent continuum (in the case of this research, the BGPs of the images, e.g., openness, depth, navigability) from binary judgments about pairs of images. The simplicity of the task makes the method particularly robust and suitable even for subjects not skilled in assessments of this type (Thurstone, 1927; Torgerson, 1958). The method consists of several operational steps, which are briefly described below. For a more detailed description of the method, see contribution 2 of this work.

- Step 1: Construction of pairwise comparisons.

Participants are presented with the images that are to be evaluated in pairs of two and are asked, for each pair, which of the two images possesses the property under investigation to a greater extent. E.g., for the expansion dimension, the question is: "In which of the two images can you see further into the distance?". According to this method, all images must be compared with all, conducting a comparison for each dimension one wants to investigate. Thus, the total number of comparisons depends on the size of the set of images to be evaluated. To find the total number of comparisons, the following formula is used: $n(n-1)/2$; where n is the total number of images. In our case, 8 images depicting natural scenery were evaluated so the number of pairings is given by $8(8-1)/2$, so in total 28 pairings were made.

- Step 2: Creation of the frequency matrix

The responses given by the participants are entered into a symmetric matrix (8x8), where each cell (i,j) indicates how many times stimulus j was preferred to stimulus i, with respect to the dimension being evaluated. A frequency matrix is created for each of the dimensions to be investigated (in our case each BGPs).

- Step 3: Creation of the proportion matrix and transformation the scores into z-scores.

This is done by calculating the proportion of preferences expressed which means to divide each value by the total number of participants. The resulting proportions are transformed into z-scores. This transformation allows differences between stimuli to be expressed in terms of linear distances between scores (David, 1988).

- Step 4: Calculation of scalar values and repositioning of the scale

For each stimulus, the average of its z-scores is calculated. The result is a scalar value that places each stimulus on an interval scale along the investigated property. To make the scoring comprehension easier, the scale can be transformed equalizing the minimum value to zero. This is done by subtracting the lowest value from all the other values, so that the lowest score becomes zero.

To measure the BGPs of the images we investigated in this work, it was decided to use the pairwise comparison method for several reasons. First of all, in the absence of validated scales to estimate complex visual properties such as BGPs, pairwise comparison provides a robust and alternative strategy to collect quantitative data. This method was considered more reliable in comparison to the classic single-image assessment with a Likert scale. In fact, pairwise comparison is a method that can reduce the complexity of the task, since judgments between pairs of images are cognitively less demanding than an absolute scale assessment. The simplification of the judgments makes it more reliable. The method also allows the production of scalar data, i.e., allows images to be placed on a continuous scale, which is useful for subsequent statistical analyses (e.g., correlations with other perceptual variables such as restorativeness). Finally, the method leads to the creation of a ranking between images, for the different analyzed dimensions; this makes the data easily interpretable through simple graphical scaling for data visualization, also facilitating subsequent operations on the images like clustering for similar image profiles.

While in Contribution 2 the pairwise comparison method was used to measure the BGPs referred to the investigated images, in Contribution 3 an additional measurement method was tested to evaluate some basic features considered to be the essential elements that make up the BGPs of an image. This is the rank order method. The basic visual features (BVFs) that were measured by using this method are:

- Visibility of the horizon line: it is estimated whether the horizon line (i.e., the straight line that ideally separates the earth from the sky) is fully visible or is partially or completely obstructed by other visual items;
- Height of the horizon line: it is estimated where the horizon line is located in relation to the set of visual items that make up the image (i.e., at the top or bottom of the scene);
- Linear perspective: is given by the presence of straight lines converging toward a single central vanishing point;
- Aerial perspective: is given by the presence of different color gradations in the image, with foreground elements marked by stronger gradations and elements in the distance with softer gradations;

- Texture gradient: is given by the ratios of proportions of repeated visual items, with larger items in the foreground compared to smaller items in the background;
- Chiaroscuro: concerns the presence of color contrasts between visual items;
- Symmetry: concerns the presence of symmetrical (i.e., mirror-like) elements, into images ideally divided vertically or horizontally;
- Collinearity: concerns the presence of lines or other elementary visual items arranged in a parallel manner along the horizontal, vertical, or oblique axis of the image.

The description of the above elements shows that they are gestalt-derived features that describe ratios and relationships between lines, colors, proportions, and other elementary items within a stimulus configuration. A brief description of the method and the reasons why it was decided to use it is given here; a detailed description of the method, the features analyzed, and the relationship with BGPs can be found in Contribution 3.

The rank order method (Torgerson, 1958) is a psychometric scaling technique that involves the simultaneous presentation of a complete set of stimuli (in our work a set of 12 images depicting natural scenes), asking participants to order them according to the degree to which they exhibit a specific property (in our work the 8 basic features investigated and described above). Each image receives a rank, representing its relative position in the ordered set of images in relation to the specific basic features investigated. The method consists of several steps:

- Step 1: Assignation of the ranks to the images.

Participants arrange the stimulus set (in our case 12 images) by ordering it from lowest to highest with respect to the evaluated property. For example, for the property "horizon line visibility", in a set of 12 images, the image evaluated as having the lowest presence of the property "horizon line visibility" receives rank 1, and the one with the highest presence of the property rank 12.

- Step 2: Construction of the rank frequency matrix.

A table is created where we record how many times each stimulus was placed in each rank, aggregating data from all participants. The result is a matrix with stimuli in columns and ranks in rows, where each cell reports the frequency with which the stimulus received that rank.

- Step 3: Calculation of the weighted sum of each stimulus for each of the investigated features.

Each cell is multiplied by the corresponding rank value. Summing by column gives the total weighted sum for each stimulus, indicative of its average perceptual "weight."

- Step 4: Proportion and z-point transformation.

The result is transformed into a proportion to the total number of comparisons (n stimuli × n participants). The proportions are then transformed into z-scores, so that differences between stimuli in the different properties investigated are expressed in terms of linear distances between scores.

- Step 6: Final scaling.

Finally, the z-scores are rescaled by zeroing the minimum value (i.e., subtracting the lowest value from all others, to bring the lowest value to zero), thus obtaining comparable scalar values on an interval scale.

Regarding the basic features of the images that were measured (i.e., horizon line height and visibility, linear perspective, aerial perspective, texture gradient, chiaroscuro, symmetry, and collinearity), despite visually accessible features, they are assumed to be complex to quantify through a classical single-image evaluation on a Likert scale. In this case, the rank order method was considered particularly suitable for the following reasons. First, the method facilitates the observer's task. Subjects do not have to estimate an absolute value but only order the stimuli, so that they can make direct comparisons between them. This reduces cognitive load and makes evaluations more reliable. Aspects such as symmetry, chiaroscuro, collinearity, etc., often emerge from the overall configuration of the image, and so the simultaneous comparison of the entire set helps participants grasp these features more effectively. Moreover, the rank order forces subjects to compare all stimuli, leading them to reflect on the entire perceptual range, limiting individual biases related to response styles (response style and response set, i.e., tendency to use extreme or intermediate responses). The method is then more efficient than others (e.g., the pairwise comparison method). It makes the task faster because the subject is faced with the entire set of stimuli. It is therefore ideal when evaluating many images on multiple properties. Finally, with respect to the use of the obtained data, ranks aggregated and converted to z-scores provide continuous measures that can be used for statistical analyses and comparisons between variables (e.g., correlations between these data, BGPs, and restorativeness indices, or regression analyses).

In the next section, an overview of the contributions contained in this work, where the hypotheses and methods of the research will be briefly taken up.

An overview of the contributions

The present work consists of three contributions aimed at investigating possible connections between the environmental psychology construct of restorativeness, the mechanisms of visual perception - particularly the processes of automatic (bottom-up) attention - and some basic features of the images which, according to gestalt-inspired perceptual theories (e.g, FIT; Treisman & Gelade, 1980; SCA; Oliva & Torralba, 2006), play an important role in the early stages of vision. Indeed, in conformity with the mechanisms of visual perception, in a preliminary visual phase, perceptual processes convert discrete items of the stimulating configuration into coarse representations of the image endowed with meaning for the viewing subject. The basic items involved in these vision processes are believed to play a role in perceiving restorativeness.

The first contribution comprises a review of the psychological literature on the role of automatic attention in the visual perception process. It aims to analyze the relationship between involuntary automatic attention and the basic features of visual stimuli, by examining experimental evidence derived from psychophysical studies. Psychophysical studies pertain to experimental psychology and perception and focus on the relationships between simple physical stimuli (e.g., color, shape, relationships of visual items) and the subject's psychological response (e.g., perception, thresholds, and reaction time). The purpose of psychophysical studies is to understand whether and how variations in a physical stimulus affect the subject's sensory or perceptual experience.

The psychophysical paradigm is considered particularly useful for studying the relationship between automatic visual attention and basic items of a stimulating visual setup for different reasons. First, psychophysics studies the direct relationship between physical stimuli and the perceptual response of subjects, to this aim it uses stimuli that are simple and controlled in quantity and intensity. Thus, this methodology of investigation allows the elements of an image to be fragmented to study the effects of the basic units of the stimulating visual configuration on the perceptual response of the subject. In addition, a psychophysical approach, relying essentially on discrimination thresholds and reaction times, makes it possible to measure, with relatively simple experimental apparatus, subjects' automatic and precognitive responses and this work is particularly interested in automatic and involuntary (bottom-up) visual attention processes. With the aim of understanding the processes of involuntary visual attention involved in visual perception, the first part of the review contains a description of the main experimental apparatuses devised in psychophysics to specifically study the relationship between involuntary automatic visual attention and the basic features of an image.

Turning to the early mechanisms of visual attention hypothesized in psychophysical studies, in agreement with gestalt-derived theories on visual perception (FIT; Treisman & Gelade, 1980; SCA; Oliva & Torralba, 2006), it is believed that, in the presence of a stimulating visual configuration (i.e, when the subject is faced with a novel environment that he or she must decode), the human visual system is called upon to quickly and efficiently select salient information in stimulus-saturated environments. For this reason, the basic properties of stimuli play a crucial role in activating bottom-up attentional mechanisms that facilitate the perceptual organization of the scene.

The first set of studies that emerged from the reviewed experimental works assumes the principles of Gestalt psychology as a theoretical framework. These postulate that visual perception is governed by innate laws (i.e., operating automatically) determining the grouping of visual elements, according to criteria of proximity, similarity, collinearity, symmetry, closure, and good continuation. Experimental evidence confirms that such relationships between elements stimulate early visual organization processes that lead to the emergence of "proto-objects". Proto objects are coherent perceptual units that automatically capture attention (Vecera & Farah, 1994; Kimchi et al., 2016). For example, studies based on *dual-task* paradigms (Moore & Egeth, 1997; Russell & Driver, 2005) show that the grouping of items based on gestalt principles influences the subject's responses even when his or her voluntary attention is directed elsewhere. This effect suggests that these preliminary perceptual processes operate at the pre-attentive level, through automatic attentional mechanisms of visual selection. Kimchi and colleagues (2004) propose a sequential model in which an initial phase of automatic clustering precedes a subsequent phase of shape formation, the former being automatic while the latter requiring focused attentional resources.

In parallel, a more recent set of studies emerged from the reviewed literature. These studies rely on more recent theories that have addressed the phenomenon of visual search for a target stimulus among distractors. These theories offer a complementary explanation of the process of early visual perception. Feature Integration Theory (Treisman & Gelade, 1980) and the Guided Search model (Wolfe, 1994; 2021) argue that certain basic features of visual stimuli - like color, luminance, spatial orientation, and shape - guide attention automatically in the pre-attentive phase of visual processing. Psychophysics experiments highlight how contrast in color and luminance between an item and its context generates the salience phenomenon and attracts attention in a bottom-up manner (Turatto & Galfano, 2000; Poirier et al., 2008). Luminance changes, in particular, are processed rapidly, serving as ecologically relevant cues for orientation in the environment (Kamkar et al., 2018).

The spatial orientation of stimuli also turns out to be a salient attribute in guiding automatic attention. *Texture segmentation* experiments (Julesz & Bergen, 1983; Dakin & Watt, 1997) show that marked differences in the orientation of visual items facilitate pre-attentive segmentation of the scene into discrete units, allowing the rapid identification of visual targets (Utochkin et al., 2018). The *pop-out* effect in visual search (i.e., when one element stands out in the scene) is most pronounced when target orientation differs significantly from that of distractors (Wolfe & Horowitz, 2017). Regarding the shape of visual items, recent studies indicate that specific geometric properties, such as closure, line intersection, and the presence of angular protrusions (spikes), exert strong attentional attractiveness. Indeed, closed stimuli - items delimited by closed lines - tend to emerge more readily as distinct objects than open configurations (items without closed lines), confirming the importance of the closure features in the pre-attentional formation of perceptual objects (Marino & Scholl, 2005; Kimchi et al., 2016).

The Gestalt theories inspired studies and the most recent visual search studies can be juxtaposed to confirm the crucial role of basic features of visual stimuli in automatic attention guidance. In particular, the reviewed psychophysical studies considered in this work show that, within a stimulating configuration, exist basic features of single items (i.e., color, luminance, orientation in the space, closure, line intersections, and the presence of spikes) and elementary relationships between items (i.e., similarity, proximity, collinearity, and symmetry) that are capable of eliciting visual attention in a bottom-up manner and, by this way, rapid construction of proto objects and a coarse perception of the scene is facilitated.

In accordance with Attention Restoration Theory (Kaplan, 1995), environments that incorporate elements capable of capturing involuntary attention without requiring effort promote the recovery of depleted cognitive resources by generating a sense of restorativeness. Therefore, identifying the basic visual properties that selectively activate automatic visual attention may be the first step in understanding which basic elements of an environment/image may promote the perception of restorativeness associated with contact with natural environments.

The second contribution presented in this work investigates the relationship between some basic and global perceptual characteristics of images - specifically the basic global properties (BGPs) theorized by the SCA (Green & Oliva, 2009) - and the perceived restorativeness (PR) of environments/images. The theoretical foundation of the study is Attention Restoration Theory (Kaplan & Kaplan, 1989; Kaplan, 1995), according to which perceived restorativeness derives from the ability of certain environments (predominantly environments with nature-like features) to automatically and effortlessly attract visual attention, promoting recovery from attentional fatigue through so-called "soft fascination". In parallel, the perceptual Scene Centered Approach (Oliva & Torralba, 2001; Green & Oliva, 2009) proposes that certain global visual properties of scenes - the BGPs, i.e., openness, expansion, depth, transience, concealment, navigability - attract visual attention in an early stage of vision and in an automatic (bottom-up) manner, allowing for a rapid understanding of the structure and function of the environment. In this way, subjects are facilitated in distinguishing between natural and built environments, the BGPs identified by the SCA being present in different amounts in natural and built environments. Indeed, although BGPs build the structure of both natural and built environments, natural environments (e.g., meadows, forests, natural vistas) tend to have higher levels of openness, expansion, depth, transience, concealment, and navigability than places where human intervention is massive (e.g., urban centers, built-up places).

Building on these theoretical assumptions - BGPs attracting visual attention automatically and making scene perception smoother - the study advances two main hypotheses:

- H1: The BGPs of a scene (i.e., openness, expansion, depth, transience, concealment, navigability), by attracting visual attention in a bottom-up manner and facilitating early scene construction, predict the four classical dimensions of PR (i.e., fascination, being away, coherence, scope).
- H2: Since BGPs are not perceived individually in a scene but constitute a whole, facilitating in this way the distinction between a natural environment and a built environment, the simultaneous presence of high levels of multiple BGPs generates an interaction effect, enhancing the perception of restorativeness, compared to the presence of a single property.

To test these hypotheses, 8 images of natural environments (4 with high and 4 with low restorativeness levels, previously assessed with the PRS-11 Scale; Pasini et al., 2014) were selected. Three independent groups of undergraduate students rated the images on the levels of the six BGPs and on the four dimensions of PR, using two measurement methods. The first method consisted of the classic single image rating with a 7-point Likert scale, and the second method consisted of comparing pairs of images with a dichotomous scale, according to the pairwise comparison method (Thurstone, 1927). The purpose of using two measurement methods was to check the concordance of the measurements, as there are no validated measurement scales for measuring the BGPs identified by the SCA. The comparison of the two measurement methods showed good agreement (Kendall's Tau >.70) for all dimensions of PR and for four of the six BGPs - i.e., openness, expansion, transience, navigability - while depth and concealment showed Kendall's Tau below the threshold of acceptability (>.50) and were therefore excluded from further analysis due to lack of reliability.

After the reliability analysis of the measurements, a subsequent phase of analysis was conducted aimed at testing the hypotheses. Regarding H1, analyses conducted using Mixed Linear Models showed significant direct effects of all BGPs on PR. In particular, openness and navigability were found to be predictors of all dimensions of restorativeness (i.e., fascination, being-away, coherence, and scope), while expansion showed significant effects on all dimensions of PR, except coherence. As for H2, an interaction effect was confirmed between functional BGPs (transience and navigability) on all dimensions of PR, and between structural BGPs (openness and expansion), but limited to the scope dimension.

These results suggest that BGPs - as global visual configurations that emerge from the combination of basic image items - may serve as early perceptual clues for the attribution of meaning to a scene. BGPs automatically and involuntarily attract visual attention, facilitating the perception of restorativeness. As BGPs levels tend to be higher in natural environments than in built environments, BGPs may be those characteristics of images that can explain the greater perception of restorativeness in natural places than in built ones. This work represents a first step toward understanding the perceptual mechanisms involved in the regenerative response that is predominantly activated in natural environments, offering theoretical and applied implications for the design of spaces capable of supporting psychological well-being.

The third contribution integrates the Attention Restoration Theory (ART; Kaplan, 1995), the Scene-Centered Approach (Oliva, 2013), and Gestalt principles of perceptual organization to explore how low-level visual features of natural environments relate to their perceived restorativeness (PR). ART posits that exposure to certain environments - particularly natural ones - can restore depleted attentional resources through the presence of specific restorative qualities, such as soft fascination and being away. The Scene-Centered Approach emphasizes that the perception of a scene's overall meaning and function is guided by global image properties (BGPs) and basic visual features (BVFs) that influence rapid scene categorization. Gestalt theories further suggest that perception is shaped by the holistic organization of basic visual elements (BVFs) according to principles such as proximity, similarity, and good continuation. The integration of these perspectives enables a psychophysical framework linking measurable image properties to psychological restoration.

Based on the aforementioned theories, in this third study, we advance two hypotheses that connect ART, SCA, and Gestalt principles guiding perception. In particular, we hypothesized:

- H1: Distinct clusters of natural environments can be identified based on their BVFs, and these clusters will reflect the different basic global properties (BGPs) identified by the SCA (i.e., openness, expansion, depth, complexity);
- H2: The different clusters obtained from the aggregation of BVFs will be significant predictors of different levels of PR, even when accounting for the random effects of participants and images.

In order to test our hypotheses, we conducted a two-part experimental study (Study 1 and Study 2). Twelve images depicting different natural environments, selected from a larger repository, served as the stimulus set for both phases. Each study involved separate participant samples, distinct measurement methods, and specific data analysis strategies to target different research questions and reduce participant fatigue. This separation also allowed the researchers to adapt the assessment approach to the nature of the variables under investigation.

Study 1 focused on the evaluation of eight Basic Visual Features (BVFs): horizon line visibility, horizon line height, linear perspective, aerial perspective, texture gradient, chiaroscuro, collinearity, and symmetry. These features were measured through a rank-order judgment method, in which participants viewed all 12 images simultaneously and ranked them from lowest to highest according to the intensity of each BVF. To avoid cognitive overload and response artifacts, the set was limited to twelve images.

The ranks obtained were transformed into z-scores and then into scalar values for quantitative analysis. The study involved 21 psychology students from the University of Verona. The selected images were standardized in size and resolution, evenly split between horizontal and vertical orientation, and balanced between scenes including water elements and those showing only green natural elements.

Two k-means cluster analyses were performed on the resulting data, both with k fixed at four, in line with the four Basic Global Properties (BGPs) proposed in the theoretical framework: openness, expansion, depth, and complexity. The first clustering used the BVFs as variables to determine whether they grouped into clusters corresponding to the BGPs. The second used the scalar BVF scores for each image to identify image groupings based on low-level visual structure. The correspondence between clusters was verified, and the image clusters were then used as predictors in Study 2.

Study 2 investigated the perceived restorativeness (PR) of the same 12 images, using single-image evaluations on a 7-point Likert scale. PR was assessed with the Italian version of the Perceived Restorativeness Scale (PRS-11; Pasini et al., 2014), grounded in Attention Restoration Theory and measuring fascination, being away, coherence, and scope. This phase involved a separate sample of 102 psychology students from the same university. Data collection was managed through the LimeSurvey online platform, accessed from individual workstations equipped with 16-inch screens. Mixed Linear Models were conducted to test whether the emerged clusters, differing in BGPs levels, predicted different levels of PR, taking into account random effects dividing both subjects and images.

Regarding the results, in Study 1, the first analysis clustered eight BVFs into four perceptually meaningful groups, labeled as Basic Global Properties (BGPs): Openness (horizon visibility, horizon height, aerial perspective), Symmetry, Texture gradient, and Expansion (linear perspective, chiaroscuro, collinearity). This clustering explained 85.8% of the variance, supporting the idea that these BVFs combine into distinct perceptual constructs. A second cluster analysis grouped the 12 images based on their BVF profiles into four image clusters: Expansion, Complexity, Texture, and Openness. This classification accounted for 68.1% of the variance, showing meaningful differences in the structural visual characteristics of the scenes.

In Study 2, Linear Mixed-effects Models tested differences in perceived restorativeness (PR) and fascination scores across the four image clusters. The models revealed significant effects of image cluster on both PR and fascination. Compared to the Texture cluster (lowest PR and fascination scores), the Complexity, Expansion, and Openness clusters showed significantly higher PR, with Complexity rated highest overall. Fascination ratings followed a similar pattern, with Complexity eliciting the strongest fascination, followed by Expansion and Openness. Post hoc comparisons showed significant differences primarily between Texture and the other clusters, and between Complexity and Openness for fascination.

These findings demonstrate that structural visual properties of natural scenes (BVFs) form distinct perceptual groups differing in BGPs that meaningfully influence the experience of restorativeness and fascination.

The following chapters will describe the three different contributions in detail. The final section entitled Conclusions contains some reflections on the theoretical and practical implications of this work.

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CONTRIBUTION 1
FROM VISUAL FEATURES TO RESTORATIVE POTENTIAL: A PSYCHOPHYSICAL REVIEW OF INVOLUNTARY ATTENTION

ABSTRACT

Research in visual perception has long investigated how the human visual system processes stimuli to generate the conscious perception of discrete objects. Automatic and involuntary attention plays a central role in early vision, selectively orienting to basic features of physical stimuli. This narrative review examines 53 psychophysical studies investigating the relationship between preattentive features and automatic attention, synthesising findings from Gestalt principles, Feature Integration Theory, and Guided Search models. Across studies, both single-item features (colour, luminance, spatial orientation, contour closure, line intersections, and the presence of spikes) and elementary inter-item relationships (similarity, proximity, collinearity, and symmetry) consistently elicit bottom-up attention, facilitating rapid scene perception and the formation of "proto-objects." These findings provide a perceptual basis for Attention Restoration Theory (ART), suggesting that restorative environments capitalise on naturally occurring features that capture attention effortlessly, supporting cognitive recovery. Implications for psychological research and future investigations on the perceptual underpinnings of restorative experiences are discussed.

1. Introduction and theoretical framework

An important topic in environmental psychology concerns the characteristics that make an environment restorative, meaning an environment that helps people recover the psychophysical energies spent during daily activities. Natural environments have mainly been shown to be restorative, and their restorative effect has been well documented. In fact, daily demands often deplete personal resources — physiological, psychological, or social — but these resources can be replenished in restorative environments (Hartig, 2004; Von Lindern et al., 2016). Two key theories explain why specific environments support recovery. Unlike urban environments, stress Reduction Theory (SRT) suggests that natural environments elicit immediate stress relief due to an innate positive affective response, leading to quicker recovery (Ulrich et al., 1991; Nukarinen et al., 2022). These responses are believed to be evolutionary and are triggered by specific environmental features (e.g., vegetation, water) that signal safety and foster well-being (Joye & Van den Berg, 2018; Hartig et al., 2014). Attention Restoration Theory (ART) (Kaplan, 1995; Ulrich et al., 1991; Kellert & Wilson, 1993) complements stress-based models by proposing that natural environments aid cognitive functioning by replenishing attention. ART distinguishes between voluntary, effortful attention and involuntary, effortless attention—the latter being automatically activated in the presence of natural stimuli (Kaplan, 1995; Kaplan & Berman, 2010). According to the theory, four environmental qualities support this restoration process: fascination, being away, extent, and compatibility (Hartig et al., 2003; Van den Berg et al., 2014; Joye & Dewitte, 2018). While ART explains how environments may promote restoration through involuntary attention, it does not specify which physical features of those environments trigger this effect. ART primarily addresses environmental experience at the level of holistic scenes, leaving unclear the extent to which low-level visual features contribute to this process. Vision science offers valuable tools for addressing this gap. Research in this field has shown that certain basic visual features—such as colour, orientation, luminance, and spatial relations like proximity and similarity—can automatically and effortlessly capture attention in a bottom-up, pre-attentive manner (e.g., Kamkar, Moghaddam & Lashgari, 2018; Ungerleider, 2000).

The present narrative review focuses on identifying, within vision science, which of these low-level features have been shown to attract involuntary attention. This constitutes the groundwork for future empirical studies—particularly in the ART context—where these candidate features can be tested for their prevalence in restorative versus non-restorative scenes. In other words, this paper does not directly test ART's claims but seeks to map the visual characteristics most likely to underpin the automatic attention processes hypothesised by the theory.

Understanding how specific visual features guide involuntary attention has been a long-standing question in vision science. Over time, several theoretical frameworks have addressed this issue, beginning with the influential contributions of Gestalt psychology. The founders of the Berlin School (Koffka, Köhler, Wertheimer) argued that the human perceptual system follows innate "rules of vision" (Wertheimer, 1923), which lead us to organise raw sensory input into structured wholes. These rules—proximity, similarity, symmetry, closure, and good continuation—govern how the visual system automatically groups elements into coherent objects, often without conscious effort. At an early stage of vision, attention is drawn to specific features of physical stimuli, or their patterns, that allow us to organise the scene into sections and meaningful objects. Later, in the 1980s and 1990s, studies on visual search discussed the role of automatic attention in the early stages of vision.

Feature Integration Theory (FIT) (Treisman & Gelade, 1980) proposes that, when faced with a stimulating configuration, attention is automatically oriented toward basic features (e.g., item's colour, orientation in space, frequency, brightness) which are analysed in parallel in a pre-attentive phase. These features constitute the basic elements that, joined together, allow specific objects to “emerge” in a scene. In the second (attentive) phase, voluntary attention is oriented toward the emerged objects. Jules and Bergen (1981) reached a similar conclusion, distinguishing two stages: a pre-attentive viewing phase, characterised by parallel, instantaneous processes over a large area of the visual field; and an attentional phase, involving serial search mechanisms over smaller areas of the visual field. In the pre-attentive process, attention is automatically attracted to basic features such as colour, size of items, line intersections, and terminations.

Wolfe and Horowitz’s contribution represents an evolution of these studies. Guided Search (GS) (Wolfe 1989, 1994, 1996, 2007, 2021) summarises the stages of visual stimulus processing as follows: (1) elements of the external world reach the visual system; (2) the system activates mechanisms that allow some stimuli to be attended earlier than others and to reach working memory (WM) for conscious perception; (3) a “priority map” is formed by multiple mechanisms, one of the most important being bottom-up guidance, according to which some basic features automatically and effortlessly capture attention. According to Wolfe and Horowitz (2017), at least a dozen basic features guide bottom-up attention, including colour, orientation in space, motion, size, shape, luminance, closure, curvature, and intersection between segments.

This paper is structured in five sections, each contributing to a better understanding of which basic visual features can elicit involuntary (bottom-up) attention. The first section describes the method used to identify and select relevant psychophysical studies for this narrative review and the inclusion criteria. The second section outlines the main experimental paradigms in vision science investigating automatic attention responses. The third and fourth sections analyse the item’s basic characteristics capable of eliciting automatic visual attention. Studies based on Gestalt “laws of vision” are presented first, followed by research on visual search processes, from FIT to Guided Search. Finally, section five compares these theoretical perspectives and considers how a better understanding of visual attention mechanisms may inform future research on restorative environments, particularly within the framework of ART.

2. Inclusion and exclusion criteria for literature review

To identify relevant studies, peer-reviewed articles were searched in the databases PsycINFO, PubMed, and Scopus using different combinations of the following keywords: "pre-attentive feature", "pre-attentive shape", "perceptual grouping", "perceptual organization", combined with "automatic attention", "bottom-up attention", "endogenous attention", and "visual attention". No temporal restrictions were applied. After removing duplicates, 163 articles were identified and screened according to the inclusion and exclusion criteria described below.

Only studies reporting psychophysical experiments related to visual attention responses were included. These experiments (e.g., visual search, texture segregation, pop-out tasks) typically involve presenting participants with simplified visual configurations composed of basic elements (e.g., lines, circles, rectangles), and measuring automatic attentional responses via reaction times or accuracy. Psychophysical studies were selected because they allow researchers to manipulate specific low-level visual features in a controlled setting. This provides a unique opportunity to examine how such features influence bottom-up (automatic) attention—the kind of attention that operates rapidly and without conscious effort, unlike top-down (voluntary) attention, which is guided by goals or expectations (Connor et al., 2004). Measures such as reaction time and percentage of correct responses serve as reliable indicators of automatic attention processes.

Studies using free-viewing paradigms, where eye movements are tracked while participants view real-world scenes, were excluded for two reasons. First, their dependent variables (e.g., gaze duration or fixation points) are not directly comparable with reaction times or accuracy. Second, because free-viewing tasks involve rich, complex imagery, they often engage higher-level, top-down processes—such as semantic memory, expectations, or personal relevance—which make it difficult to isolate the effects of low-level features. Similarly, studies using neuroimaging or involving participants with neurological impairments (e.g., visual neglect syndrome) were excluded. While these approaches contribute important insights into the neural mechanisms of vision, the nature of their data (e.g., brain activation patterns) differs substantially from the behavioural indicators used in psychophysics and would not allow direct comparisons. Also excluded were theoretical papers, reviews, meta-analyses (n = 5), and empirical studies with unclear methods or insufficient participant information (n = 3).

Following this screening process, 47 peer-reviewed studies were retained. An additional six studies were identified by examining reference lists of selected articles, bringing the total to 53 studies (See table 1). All included studies employed within-subject laboratory designs, and most used student samples (64%).

3. Main experimental apparatuses used in psychophysics to study automatic involuntary visual attention

This section describes the main apparatuses reported in the 53 studies included in this narrative review, all of which were designed to investigate the functioning of automatic, involuntary (bottom-up) attention in the early stages of vision. While these paradigms are also commonly employed in other research not covered here, the review focuses specifically on those that emerged from the selected studies. Broadly, studies of visual attention have identified three main mechanisms: (1) space-based attention; (2) object-based attention; and (3) feature-based attention. They can operate separately or jointly (Wegener et al., 2014; Kravitz & Behrmann, 2011; Chapman & Stormer, 2021). Until the 1980s, visual attention was believed to operate primarily within spatial boundaries (Hoffman & Nelson, 1981; Egly et al., 1994). In this paradigm, attention is conceived as a "zoom lens"; once it has focused on a specific area of the image, it can automatically and simultaneously process everything within that area. Later, the idea was developed that attention, in addition to being space-based, can be object-based, i.e., as soon as an image is presented to the subject, attention is automatically drawn to the objects that "surface" from it. The object surfacing (i.e., object's perception) is possible due to the combination of basic features of the stimulating configuration (Baylis & Driver, 1992; Kimchi, Yeshurun and Choen-Savransky, 2007). Finally, the feature-based theory holds that visual attention, rather than being attracted to objects per se, is automatically oriented to specific basic features of the image, such as line closure, shape, colour, and orientation in the space (Treisman & Gelade, 1980; Wolfe, 1994; 2021; Wolfe & Horowitz, 2017).

A very common apparatus used in psychophysics to investigate this topic was devised by Duncan (1984). Based on the object-based visual attention paradigm, participants are presented with a stimulating configuration which, due to the combination of certain basic features identified by the Gestalt laws of vision (i.e., closure and good continuation), is perceived as an image composed of two overlapping objects: a rectangle containing a bar. The rectangle and the bar differ in two elements. The rectangle can be narrow or wide, with an opening on either the right or left side, while the bar can consist of dots or a dashed line and can be tilted to the right or left. In different trials, participants are asked to identify, as quickly as possible, either one feature of an object, two features of the same object, or two features belonging to different objects (one for the rectangle and one for the bar). It is hypothesised that the two objects that "surface" from the configuration will attract attention if the task is guided by object-based visual attention. Consequently, responses regarding reaction times (RTs) and accuracy should be better when participants judge two features of the same object than when they judge two features of different objects, as attention must be redirected between objects in the latter case.

A second apparatus based on object-based attention is the flanker task paradigm, first used by Eriksen and Eriksen (1974). In this task, a target is presented, and participants must indicate whether it possesses a specific feature. The target is flanked by two distractor items. Depending on how the items are organised according to Gestalt principles (e.g., similarity in colour, connection, good continuation), the target and distractors may be perceived as parts of the same perceptual object in one condition, or as distinct objects in another. Suppose the task is driven by object-based attention. In that case, distractors are expected to exert greater interference on target feature detection when target and distractors are perceived as part of the same object than when they are seen as separate objects.

A third experimental paradigm based on object-based attention is linked to dual-task studies (Moore & Egeth, 1997; Kimchi & Razpurker-Apafeld, 2004). In these experiments, participants perform a primary task that requires focused attention—for example, comparing features of two target items. At the same time, researchers examine whether the unattended elements of the stimulus are automatically grouped according to Gestalt principles and perceived as a background of discrete objects that can influence judgments about the targets. It is hypothesised that if visual attention mechanisms are primarily object-based, even when participants focus on a target, the "proto-objects" in the background can affect evaluation of the overall stimulus configuration.

A similar apparatus is the change detection task devised by Russel and Driver (2005). In this paradigm, participants are shown two displays in succession, separated by a mask. Their task is to judge whether a central target—usually a square composed of smaller squares—remains the same or changes between the two displays.

Meanwhile, other elements in the background can be grouped into shapes according to Gestalt principles. The target and the background configuration may change or remain the same across trials. It is hypothesised that if grouping and the formation of "proto-objects" occur through automatic attentional processes, responses will be influenced by a "congruence effect." Specifically, if the target remains unchanged, reaction times and accuracy will be higher when the background also remains unchanged; conversely, if the target changes, performance will be better when the background changes as well.

The experimental apparatus devised by Egly, Driver, and Rafal (1994) tests both space-based and object-based attention. Participants view two vertically aligned rectangles placed side by side. At the start of each trial, attention is cued to one short edge of one rectangle by briefly enlarging that edge. Immediately afterwards, a target appears in one of three locations: (1) at the cued edge (valid condition), (2) at the opposite edge of the same rectangle (invalid same-object condition), or (3) at the corresponding edge of the other rectangle (invalid different-object condition). The task is to locate the target as quickly as possible. The hypothesis is that, once attention is drawn to a part of an object, processing is facilitated for other locations within the same object. Thus, targets in the invalid same-object condition should be found more quickly than those in the invalid different-object condition.

The paradigm of Cole, Gellatly, and Blurton (2001) focuses entirely on the space-based attention hypothesis. Each trial begins with a fixation point (a cross on a white screen), followed by the appearance of a figure (either a square or a rectangle). Shortly afterwards, a target is presented outside the figure but in a nearby area of space. The target can appear either adjacent to one of the figure's corners or next to one of its long sides. It is hypothesised that corners attract more visual attention than long sides because they represent the Gestalt feature of two intersecting lines. If attention is space-based, stimuli located in the space adjacent to these salient parts should be processed more quickly, leading to shorter reaction times when the target appears near a corner compared with a long side.

Turning now to the concept of feature-based attention—according to which attention in the early stages of vision is directed towards basic features of stimuli that, when combined, give rise to the perception of discrete objects (Treisman & Gelade, 1980)—a first experimental paradigm is the texture segregation or texture segmentation task (Julesz & Bergen, 1981). In this task, participants view a display containing basic items (e.g., lines with different slants, L-shaped segments, small triangles, elongated shapes resembling the letter

'R') and indicate whether they perceive a foreground figure standing out from the background. The aim is to test whether certain items in the display, made salient by their basic features (e.g., colour, slant, intersections of segments), enable a figure to perceptually emerge and dominate over the background.

Another widely used paradigm associated with the feature-based attention hypothesis is the visual search task (Wolfe, 1994; 2001). In these tasks, participants are required to locate a target within a display containing multiple distractors, while reaction times (RTs) and accuracy are recorded. Search efficiency is typically assessed by examining the slope of the function relating RTs to the number of items in the display. Intuitively, as the number of items increases, search becomes slower because each item must be examined until the target is found. In most cases, a larger number of items results in longer RTs, producing a steep slope. However, in some cases, the number of items has little or no effect on RTs, resulting in a flat slope. This occurs when the target contains a basic visual feature—such as a distinctive colour, luminance, or orientation—that makes it salient, thereby attracting bottom-up attention and allowing detection without the need for a time-consuming, item-by-item serial search.

Visual pop-out experiments (Nothdurft, 2005; Casco, Grieco, Giora, and Martinelli, 2006; Pramod & Arun, 2014) are a variation of visual search tasks. In this case, one item in the stimulating configuration stands out from the others because it has a basic feature that attracts bottom-up attention. Participants are asked to identify the item that pops out as quickly as possible.

Finally, a paradigm that deviates from the traditional ones described above is constructed on a "genetically based algorithm" (Van Der Burg, Cass, Theeuwes and Alais, 2015; Aizenman, Ehinger, Wick, Micheletto, Park, Jurgensen and Wolfe, 2022). It is inspired by the biological processes that drive natural selection in the evolution of species. In biological evolutionary processes, genetic traits combine, and traits that have proven to be "successful" in their relationship with the environment are passed on, while inefficient ones are extinguished. In this type of experiment, participants are engaged in several blocks of trials to search for a target within distractors (e.g., find a horizontal red line between lines of different slopes and colours). When the first block of trials is completed, they proceed to the second block, which consists of new distractors whose characteristics were derived by combining the characteristics of the distractors from the previous block. This creates a new "generation" of distractors, which makes the target search task more complex. Successive blocks of trials are presented in which new "generations" of distractors are created repeatedly until the RTs in target detection become stable. This experimental apparatus is also based on feature-based visual attention; by changing the characteristics of distractors, one can understand which basic features attract more bottom-up visual attention, making target finding more difficult.

4. Basic features considered by the "Gestalt Laws of Vision"

The line of research inspired by the Gestalt School's theories uses psychophysical experimental apparatuses to study the mechanisms of perceptual organisation that make possible the shift from a physical stimulating configuration to the perception of different objects in one meaningful scenario. According to Gestalt (Wertheimer, 1923; Koffka, 1935; Rubin, 1921; Sekuler & Bennett, 2001; Lee & Blake, 1999; Beck & Palmer, 2002; Palmer & Beck, 2007; Wagemans et al., 2012), there are two fundamental mechanisms of perceptual organization: 1. Grouping, a process by which the human visual system groups physical items according to basic relationships between them (i.e., proximity, similarity, continuity of direction, common orientation in the space, closure, structural coherence, restless articulation), 2. Figure-background articulation, according to which the human visual system divides the percept into figures (i.e, compact elements, with objective character, capable of attracting attention) and background (i.e., indefinite space). This process is also based on basic relationships between physical items (i.e., the smaller area, included in larger areas, with convex edges, whose axes tend to coincide with the vertical or horizontal axes of the space, is perceived as a figure). There are two orders of evidence showing that, at an early stage of vision, visual attention is capable of automatically, involuntarily, and effortlessly grasping the relations between items described by the Gestalt laws of vision (i.e., these items' relationships attract attention in a bottom-up manner), and precisely: 1. the perceptual organization of the scene into "proto-objects" and figure-background articulation occurs automatically, even though voluntary attention is focused on a different task; 2. "proto-objects" that have emerged from the scene attract visual attention in a bottom-up manner. The following two paragraphs describe experiments from the 53 studies retained for this review that illustrate these phenomena.

4.1. Automatic Formation of Proto-Objects and Figure-Ground Organisation

This section lists experiments showing that, in the early stage of vision, visual attention automatically directs itself to certain basic relations between items, identified by Gestalt, that make possible the formation of "proto-objects" which, in turn, facilitate the perceptual organisation of the scene. In fact, according to the evidence reviewed, grouping and figure-background segmentation occur even if the subject's voluntary and direct attention is engaged in another task.

Within the paradigm of dual-task studies, Moore and Egeth (1997) have used a display in which two lines of equal length appear on a background of black and white dots. In some trials, dots are organised according to the Gestalt principle of similarity in item colour, thus forming the Ponzo Illusion or the Müller-Lyer Illusion. As is known, within these optic-geometric illusions, two lines of equal size appear one longer than the other. The authors have shown that, although participants' direct attention is focused on the two lines, pre-attentively the dots are organised according to the optic-geometric illusion, influencing participants' responses. In fact, the RTs for correct responses (i.e., the two lines have the same length) were higher on trials where the optic-geometric illusion appeared than on trials where the dots were randomly arranged. Interestingly, at the end of the trial, participants were asked to indicate the geometric figure according to which they had arranged the percept, but they, in most sections of the trials, could not give an answer. Chan and Chua (2003) replicate Moore and Egeth's (1997) experiment and find the same results by having participants compare two lines of equal length placed against a background of dots that, via the Gestalt principle of similarity in dimension, are perceptually organised in the Müller-Lyer Illusion. One critique that can be made of Moore and Egeth's experiment is that the items in the background may not be sufficiently different and separate from the target, so it may be that the attention focused on the target had processed these stimuli as a target itself. To reject this doubt, Russel and Driver (2005) use a change detection task in which participants are presented with two displays in succession, separated by a 150-ms mask. The task consists of answering whether a target in the centre of the scene (i.e., a square composed of a number of smaller squares) is the same or different in the two displays. In the background, some circles can be grouped into rows or columns, according to the Gestalt principle of similarity by colour. In the different trials, both the target and the background configuration can change or remain the same. In five different experiments, the item positions were varied to ensure that the background circles were sufficiently spaced apart and clearly distinguishable from the central target. Again, the grouping of the background into rows or columns has been shown to occur pre-attentively; in fact, the responses were affected by the "congruence" effect whereby, if the target remained unchanged, the speed in response and the number of correct responses was greater when the background also remained unchanged, whereas, if the target changed in the two displays, the responses were better if the background also changed. Lamy, Segal, and Ruderman (2006) also conducted four change detection experiments. Participants must judge a target letter in a background composed of small squares of different brightness. In some conditions, the squares are randomly arranged; in others, the squares are grouped by similarity, forming a letter in the background that may be compatible or incompatible with the target. The authors have shown that the grouping of items forming the background occurs pre-attentively; despite this, the background influences the judgment about the target. Indeed, the "congruence" effect was found; in fact, RTs in the condition where the target was compatible with the letter in the background were shorter than in the condition in which the target and background were incompatible. Kimchi, Rrazpurker and Apafeld (2004) have argued that the process of grouping proceeds in two stages: the first of "clustering" (i.e., mere formation of groups of similar stimuli), which involves automatic attention; the second of "shape formation," which involves direct attention instead. To test the hypothesis, the paradigm of Russel and Driver (1995) was adopted: participants are presented with two displays in succession; the task is to say whether the square in the centre of the display is the same or different in the two exposures. There are two conditions for the square: 1. same target (i.e., identical squares in the two displays), 2. different target (i.e., different squares). As for the background, the conditions are 1. columns/rows condition (i.e., the items, via the Gestalt principles of similarity in colour and proximity, are grouped in columns or rows), 2. triangle/arrow condition (i.e., the items, via the Gestalt principles of similarity in color and proximity are grouped in the shapes of triangles or arrows), 3. control (i.e., in the background there are triangles or arrows formed by continuous lines). The experiment has shown that the "congruence" effect occurs only in the columns/rows condition, confirming the hypothesis that only the "clustering" phase occurs under the effect of automatic (bottom-up) attention. Again, when participants were asked what geometric figure was in the background, although the majority reported being aware of the presence of a background (86% in the columns/rows condition and 93% in the triangles/arrows condition), no participant (14 participants) remembered the shape in the background. These findings demonstrate that, even when voluntary attention is engaged elsewhere, the visual system automatically organises items according to similarity, allowing Gestalt-based grouping processes to influence perception pre-attentively.

Kurylo (1997) has explored the issue of the spatial relationship between items more deeply. Using a texture segmentation paradigm, he showed participants a display composed of dots immediately followed by a mask. Subjects are asked to indicate whether they perceived an image composed of dots arranged in columns or rows. The dots can be pre-attentively grouped according to their proximity (condition 1) or good continuation (i.e., elements that line up on an imaginary straight line, condition 2). The experiment has shown that visual attention automatically detects both the relationship (proximity and good continuation) between items, but grouping by proximity is faster (mean 87.6 mls) than grouping by good continuation (mean 118.8 mls). Thus, proximity exerts more force on automatic attention than good continuation. However, Han (2004) compares proximity and similarity between items. Again, experimental subjects perform a texture segmentation task: they are presented with a display of white rectangles and circles on a black background. The task is to indicate, as quickly as possible, whether the items are organised in rows or columns. In the different displays, items can be grouped pre-attentively or via their relationship of closeness or similarity. There are two different experimental conditions: 1. congruent (i.e., both proximity and similarity drive toward the same grouping process), 2. incongruent (i.e., proximity drives toward one type of grouping and similarity toward the opposite grouping process). RTs and accuracy in responses are measured. Results showed that when proximity and similarity conflicted, RTs slowed down, and proximity produced a more substantial and earlier effect on grouping than similarity. Taken together, the evidence indicates that automatic attention is sensitive to both proximity and good continuation, but proximity exerts a stronger and earlier influence on perceptual grouping than either similarity or continuation.

Following Gestalt theories, automatic and involuntary visual attention can also quickly detect the difference between concave and convex areas of an image; this facilitates the process of figure-ground segmentation. Indeed, if in an image there are concave and convex sections, ceteris paribus, the convex ones will be perceived as figures and the concave ones as background (Kanizsa & Gerbino, 1976; Peterson & Salvagio, 2008). Kimchi and Peterson (2008), in a change-detection task, ask participants to compare two displays in sequence, on which a target consisting of a small matrix of 12 white and 13 black squares is placed. In the two displays, the target can change (i.e., there is a change in the position of one square; different target condition) or remain the same (same target condition). The target appears against a background composed of eight regions that are identical in size, contrast in luminance, symmetry, and orientation in space; the only difference is that the regions are bounded by concave or convex edges, alternating with each other. The regions in the background can change or remain identical in the displays. It was shown that even though the subject's voluntary attention was focused on the target, visual attention automatically captured the concavity/convexity of the background areas in fact, the "congruence" effect was found, i.e, RTs and accuracy in responses were better, in the same target condition, when also the background did not change and, in the different target condition, when the background also changed. Overall, the results confirm that automatic visual attention contributes to figure–ground organisation by privileging convex over concave regions, thereby guiding perception toward figure assignment even in the absence of voluntary attention.

Taken together, these studies show that automatic visual attention plays a crucial role in the early stages of scene analysis by detecting fundamental Gestalt relations—similarity, proximity, continuation, and convexity—that enable the rapid formation of proto-objects and support figure–ground segregation without requiring voluntary control.

4.2.Bottom-Up Capture of Attention by Gestalt-Driven Proto-Objects

In the previous section, evidence was shown concerning the fact that the human visual system automatically organises a stimulating configuration by following the basic relations between items identified by Gestalt's principles, even when the subject's voluntary attention is engaged in another task. In this section, a complementary concept is investigated: the fact that, after the percept has been organised into coherent units (i.e., proto-objects) via gestaltic relations between items, attention is automatically attracted to proto-objects. Evidence of this kind aligns with the object-based attention hypothesis, according to which the visual system pre-attentively organises the scene into proto-objects, then selects the objects to which direct voluntary attention (Scholl, 2001).

Vecera and Farah (1994), Kramer, Weber, and Watson (1997), and Behrmann, Zemel, and Mozer (1998) replicated Duncan's (1984) classic overlapping objects experiment, consistently demonstrating the same-object advantage effect. In Duncan's apparatus, a briefly presented display is perceptually segmented into two distinct objects—a rectangle and an overlapping line—through the Gestalt principles of closure, proximity, and good continuation. These objects automatically attract attention. Each object can vary along two dimensions: the rectangle may be large or small and opened on either the left or right side, while the line may be clockwise or counterclockwise and composed of dots or dashes. Participants are asked to judge these dimensions under a 2 × 2 experimental design: Object factor: (a) same-object judgments, where both features belong to the same object, vs. (b) different-object judgments, where features belong to different objects. Judgment factor: (a) single-judgment blocks, requiring evaluation of one feature only, vs. (b) double-judgment blocks, requiring sequential evaluation of two features. Accuracy rates showed a robust same-object advantage. Judging two dimensions of the same object was easier than judging one dimension from each object. In the double-judgment condition, accuracy for the second feature remained stable when both belonged to the same object, but declined when they belonged to different objects—indicating that attention, automatically engaged by the first object, must be reallocated to the second. Kramer, Weber, and Watson (1997) extended Duncan's paradigm by introducing a post-display probe. Immediately after the two-object judgment task, a red dot was presented either in the location previously occupied by the judged object or elsewhere. Results showed higher accuracy for same-object judgments and faster detection of the probe when it appeared in the space of the attended object, further confirming that attention is object-based and automatically drawn bottom-up. Behrmann, Zemel, and Mozer (1998) demonstrated that the same-object advantage persists even under occlusion conditions, requiring amodal completion. They presented two partially overlapping rectangles forming an "X," with portions of each rectangle hidden. Participants judged features of the rectangles' short sides, which could be straight or curved with indentations. Once again, judgments were more accurate when both features belonged to the same rectangle than to different rectangles. The described studies lead to the supposition that attention is processed more efficiently within the boundaries of a single object than across multiple objects, suggesting that proto-objects automatically guide attentional allocation.

Several studies (Macquistan, 1997; Chen, 1998; Moore, et al., 1998; Prett & Sekuler, 2001; Marino & Scholl, 2005; Hecht & Vecera, 2007; Drummond & Shomstein, 2010) have shown the same object advantage effect through the use of the spatial pre-cuing paradigm by Egly, Driver and Rafal (1994). In this type of trial, participants are presented with a stimulating configuration that, due to the Gestalt relations between items of proximity, closure, and good continuation, is perceived as two rectangles placed side by side, vertically or horizontally oriented, depending on the trials. For the duration of the experiment, participants must stare at a point in the centre of the display; while they are focused on the fixation point, their attention is drawn to an edge of one of the two rectangles (i.e., this edge becomes brighter for a very short time). Immediately afterward a target (i.e., a white square) appears; in some trials (75%) the target appears in the area of the rectangle to which attention was drawn (valid-cued condition), in 17.5% the target appears in the same rectangle but in another area (invalid within-object shift condition), in the remaining 17.5% the target appears in the other rectangle (invalid between-object shift condition). The participants' task consists of pointing out where the target is as quickly as possible. All the experiments showed that, once attention has been directed to one side of one of the two rectangles, it automatically spreads to the whole rectangle. Comparing the invalid within-object shift and invalid between-object shift conditions, target-finding performance was always worse (i.e., longer response times) when, in order to find the target, attention had to be redirected from one rectangle to the other. As the distance and direction of the targets in the two conditions (within-object and between-object) were always the same, so too the same retinal eccentricity was preserved, the delay in response can be attributed to the need to shift attention from one rectangle to the other. This fact supports the hypothesis that, once a perceptual object is formed according to the relations between items identified by Gestalt (i.e., proximity, collinearity, or good continuation and closure), it draws attention to itself in a bottom-up manner. Several variants of the spatial pre-cuing paradigm developed by Egly, Driver, and Rafal (1994) have been proposed, all of which report the same object advantage effect. Moore, Yantis, and Vaughan (1998) and Pratt and Sekuler (2001) demonstrated that Gestalt relations—specifically proximity, good continuation, and closure—automatically capture attention, enabling the perceptual formation of two rectangles even when the figures are partially occluded. Pratt and Sekuler (2001) introduced two additional conditions to Egly and colleagues' paradigm. In the completion condition, after 1,000 ms of exposure, a cross appeared at the centre of the display, partially occluding the two rectangles. In the non-completion condition, the cross did not appear. Participants' response times (RTs) for correct trials were analysed using an ANOVA, with condition (completion vs. non-completion) and target position (validly cued, invalid within-object shift, invalid between-object shift) as factors. The analysis revealed a main effect of target position: responses were faster when the target required a shift within the same object and slower when it required a shift between objects. Although no significant differences emerged between the completion and non-completion conditions, the results confirmed that perceptual objects were formed even when partially occluded, consistent with the operation of amodal completion mechanisms. These findings show that, when attention is directed to part of an object, it involuntarily spreads to the entire object. Shifting attention across objects is slower and less efficient, showing that perceptual organisation based on Gestalt principles constrains how attention is distributed in space.

Marino and Scholl (2005) have focused on the gestaltic feature of closure; they, referring to Avrahami (1999), assert that the closure enables the contour-based line-tracing process (i.e., the formation of object edges that promotes object detection). The authors repurpose the experiment of Egly, Driver and Rafal (1994) by comparing the strength of the object-based advantage effect when the edges of the two rectangles are completely closed versus when they are not (in the latter case, the two short sides of the rectangles are removed so that only the four parallel lines, positioned side by side, are conserved). They found that the object-based advantage effect was produced even when the rectangle's edges were not completely closed, but this effect was greater when the two closed rectangles appeared on the display. Thus, closure is an important basic Gestalt feature for forming perceptual objects that attract attention in a bottom-up manner. Another line of evidence comes from the Flanker Task (Eriksen & Eriksen, 1974), which demonstrates that visual attention within a stimulus configuration is automatically directed toward perceptual objects that "emerge" through Gestalt relations. In this paradigm, the display always contains a central target flanked by distractors, and—unlike the paradigms described above—the target location is known in advance. The critical hypothesis is that if Gestalt-based grouping attracts attention in a bottom-up manner, distractors will exert stronger interference when they are perceived as belonging to the same object as the target, compared to when they are grouped into a separate object. Chen and Cave (2006) adapted the task by presenting visual stimuli that, through Gestalt principles of closure and good continuation, were perceived as a rectangle (50% of trials vertical, 50% horizontal) flanked by two additional rectangles. The target, a letter (H or S), always appeared in the central rectangle, while distractors appeared to its sides. Four conditions were tested: when the target and distractors were on the same rectangle and distractors were neutral (the letter O), when the target and distractors were on the same rectangle but distractors were incompatible (H or S), when the target was on the central rectangle with neutral distractors on the flanking rectangles, and when the target was on the central rectangle with incompatible distractors on the flanking rectangles. Response times (RTs) and accuracy were measured. Results showed that RTs were slower when target and distractors belonged to the same perceptual object than when they were placed on different objects. RTs were also faster in the neutral conditions than in the incompatible conditions. Crucially, in the incompatible condition, interference was greater when distractors were grouped within the same object as the target (mean delay of 32 ms) than when they were located in different objects (mean delay of 15 ms). Taken together, these findings support the view that even when the target location is known and attention is intentionally focused on that position, perceptual objects formed through Gestalt relations automatically capture attention. Consequently, distractor elements that share the same object as the target are processed and interfere more strongly, revealing the bottom-up nature of object-based attention. Richard, Lee, and Vecera (2008) adapted the flanker-rectangle paradigm by replacing letters with convex shapes, either circular or quadrangular. They observed longer response times when the target and distractors were incompatible—for example, a circular target with a rectangular distractor—but this effect was statistically significant only when the target and distractors were perceived as parts of the same perceptual object, that is, the same rectangle. Similarly, Baylis and Driver (1992) and Chen (2000) employed comparable experimental configurations in which the stimuli, organised through basic Gestalt principles of proximity and colour similarity, were perceived as a series of irregular, horizontally aligned hexagons. Participants were asked to compare the vertices of the outer sides of the central hexagon and indicate which side, left or right, was lower. By manipulating the configuration, the two sides could either be perceived as part of a single hexagon (Single Object condition) or as belonging to two distinct hexagons (Two-Objects condition). Results demonstrated that participants responded faster and more accurately when the sides were perceived as part of the same object compared to when they were seen as belonging to two separate objects. These findings reinforce the view that perceptual objects formed through Gestalt relations automatically guide attention, enhancing processing efficiency for features within the same object while limiting interference from features associated with distinct objects. Kerzel, Born, and Schönhammer (2012) provided evidence that attention is preferentially directed toward perceptual objects formed through basic Gestalt relations, such that distractors appearing outside the attended object exert minimal interference. In their experiment, 18 stimuli—rhombus-shaped figures except for a single circle-shaped figure—were arranged so that similarity in colour and proximity organised them into two concentric rings, producing the perception of a smaller ring within a larger ring. Participants were instructed to fixate on a central point and to detect a target line embedded within the circle-shaped item, reporting as quickly and accurately as possible whether the line was vertical or horizontal. In each block of trials, the target was consistently positioned either in the smaller or the larger ring, allowing participants to focus their attention on one of the two perceptual objects. Distractors were present in 50% of trials: in 25% of trials, a colored distractor appeared in the same ring as the target, while in the remaining 25%, the distractor appeared in the other ring. The authors hypothesised that if the perceptual object automatically captured attention, distractors would produce greater interference when located within the same ring as the target than when appearing in the other ring. The results confirmed this hypothesis. Reaction times were longest when distractors appeared in the same ring as the target, compared with trials without distractors or trials in which distractors were in the opposite ring, whereas the size of the ring containing the target had no significant effect. Similarly, the number of incorrect responses was higher when distractors were presented within the same ring as the target. These findings support the notion that attention is drawn in a bottom-up manner to perceptual objects defined by Gestalt relations, reducing the influence of distractors outside the object. These findings show that distractors inside the same object interfere more strongly with target processing than those outside, and that even task-irrelevant objects can capture attention automatically.

Kimchi (2009) raised several critiques regarding the experimental paradigms discussed above. While these studies demonstrate that items organised into perceptual objects through Gestalt relations attract visual attention in a bottom-up manner, the attention-attracting object is never entirely neutral or irrelevant to the task. Typically, either a section of the object is temporarily made more salient (e.g., Egly, Driver, & Rafal, 1994) or the target itself is part of the attention-attracting object (e.g., Duncan, 1984; Eriksen & Eriksen, 1974). To address this limitation, Kimchi and colleagues developed paradigms in which the attention-attracting object is completely task-irrelevant. In one study, Kimchi, Yeshurun, and Cohen-Savransky (2007) presented participants with displays in which the task was to identify, as quickly as possible, the colour of a target letter "L" appearing above or below an asterisk. Each trial began with a fixation point displayed for 500 ms, followed by task instructions for 1,000 ms indicating the expected location of the target, and then a configuration of nine green and red Ls oriented in different directions for 500 ms. Finally, the asterisk, which was the focus of attention, appeared. The asterisk's placement defined three experimental conditions: it could appear inside a perceptual square formed by some of the Ls according to Gestalt principles of closure, collinearity, and symmetry (Inside Object), outside the square in a different area of the screen (Outside Object), or in a display without any square (No Object). The authors hypothesised that if perceptual objects automatically attract attention, response times would be faster in the Inside Object condition than in the Outside Object condition, as attention would already be aligned with the object, and faster in the No Object condition than in the Outside Object condition, where no object competes for attention. Repeated-measures ANOVA confirmed these predictions: responses were faster in the Inside Object condition compared with the Outside Object condition, and slower in the Outside Object condition compared with the No Object condition. Notably, the perceptual object in this study was completely irrelevant to the target, yet it still captured attention when present. Subsequent studies extended these findings. Yeshurun, Kimchi, Sha'shoua, and Carmel (2009) replicated the paradigm with 16 L-shaped stimuli, sometimes organised into a square, and a Vernier stimulus (typically consisting of two line segments that are slightly offset relative to one another, which is commonly used in vision research to measure fine spatial resolution and alignment sensitivity) as the target. Reaction times were shorter when the target appeared inside the square than outside it, although no significant difference emerged between the Outside Object and No Object conditions. Kimchi, Yeshurun, Spehar, and Pirkner (2016) further examined the phenomenon with 36 L-shaped stimuli and a Vernier target, confirming that attention is drawn not only to the object itself but also to the space it occupies. Even when the target appeared only after the square had disappeared, response times were faster in the Inside Object condition compared with the Outside Object condition, and faster in the No Object condition than in the Outside Object condition. Manipulating the distance between the square and the target in subsequent trials revealed that, in the Outside Object condition, response times were faster when the target was closer to the square. Finally, the "strength" of the Gestalt relations forming the attention-attracting object was investigated. Collinearity alone could generate an attention-attracting object, whereas symmetry alone could not. However, combining symmetry with good continuation was sufficient to form such an object. Attention was also captured by Kanizsa's (1980) illusory square, which required pre-attentive amodal completion to perceive. Together, these studies demonstrate that perceptual objects formed by robust Gestalt relations can automatically draw attention, even when entirely irrelevant to the task. These findings show that distractors inside the same object interfere more strongly with target processing than those outside, and that even task-irrelevant objects can capture attention automatically.

Taken together, these findings show that involuntary attention is fundamentally object-based: once elements are organised into objects, attention is automatically drawn to them and constrained by their boundaries. This section has provided a body of evidence from Gestalt studies showing that, when observers are presented with a stimulating visual configuration, basic Gestalt relations—such as proximity, similarity, good continuation (collinearity), symmetry, closure, and convexity/concavity—can automatically attract attention in a bottom-up, pre-attentive manner, supporting the formation of "perceptual objects" on which visual attention is directed. Based on the reviewed experiments, a tentative hierarchy of these Gestalt relations emerges in terms of their ability to capture attention: proximity and similarity are the strongest and most immediate cues, followed by good continuation, symmetry, closure, and, finally, convexity/concavity, which appears more context-dependent. This evidence highlights which low-level structural features of visual scenes operate involuntarily to guide attention, providing a foundation for subsequent analyses aimed at assessing whether these features are present in restorative environments, as predicted by Attention Restoration Theory.

5. Basic features considered by visual search theories

In parallel to Gestalt's studies about shape formation (i.e., grouping between items) and figure-ground segmentation, a second vein of literature is useful in understanding the basic features that, in a stimulating configuration, attract visual attention automatically and in a bottom-up manner, that is, literature concerning visual search studies. These studies are interested in visual and attentional mechanisms that allow us to quickly detect an item when we are searching for it among a number of different stimuli (Treisman & Gelade, 1980; Wolfe et al., 1989; Donk & van Zoest, 2008; Lleras et al., 2020; Wolfe, 2021). Feature Integration Theory (FIT; Treisman & Gelade, 1980) splits the process of visual search into two stages: 1. an early stage of vision, during which the visual system processes automatically (i.e., without attentional effort) and in parallel only a few basic features of the scene (i.e., color, brightness, orientation in space); 2. a subsequent step, in which the basic features are joined together in order to form the perceptual representation of objects. This second step requires serial processes involving attentional effort. Wolfe's Guided Search model (GS, Wolfe, 1994; Wolfe & Gancarz, 1996; Wolfe & Gray, 2007; Wolfe, 2021) is an evolution of FIT. The author argues that the visual system is able to process pre-attentively and in parallel many more items than those identified by FIT. This operation does not occur randomly, but attention is guided by precise rules toward some specific elements in the scene, so some items will be processed earlier than others. One of the main aspects of these rules is bottom-up guidance, according to which visual attention is automatically and effortlessly directed toward some salient basic features. In visual search, the salience of a basic feature increases when the target differs strongly from the distractors, and when the distractors themselves are relatively similar to one another (Desimone & Duncan, 1995; Kastner & Pinsk, 2004).

Following these theoretical models, the present section examines which basic features have been shown to capture attention in a bottom-up manner. In line with the classification proposed by Wolfe and Horowitz (2017), we focus on colour, luminance, orientation in space, and shape (further subdivided into closure, segmentability, and spikiness). In the next part, we review experimental findings that illustrate how these features influence attentional capture in visual search paradigms.

5.1. The colour and luminance of visual stimuli

A number of psychophysical experiments have shown that contrast in colour and luminance between an item and its neighbours generates the phenomenon of salience and elicits bottom-up attention. In Carter (1982), participants have to search for a target (i.e., a three-digit number whose colour is known in advance) among several distractors (three-digit numbers of different colours). The results of the experiment showed that target search time increased significantly when the number of distractors of the same or similar colour as the target increased. The RTs, however, did not increase when the target and distractors differed significantly in colour. Moraglia, Maloney, Fekete and Al-Basi (1989) devised a visual search task in which participants indicated whether a coloured target was present (50% of trials) or absent (50%) among distractors of different colours. The results showed that when the target differed strongly in colour from the distractors, reaction times were short regardless of target presence. However, as the colour similarity between target and distractors increased, reaction times also increased, indicating a shift from automatic detection to a serial, item-by-item search process. Turatto and Galfano (2000) asked participants to detect a vertical line among distractors with different orientations. All lines were placed inside six circles, five of the same colour and one of a different colour. Detection was faster when the target appeared in the differently coloured circle, indicating that attention was automatically drawn to it. In a follow-up study, Turatto and Galfano (2001) used a similar task with a rotated letter T (target, 50% present) among rotated Ls (distractors), each enclosed in one of eight circles, seven of the same colour and one different. Again, the odd-coloured circle captured attention: responses were faster when the target appeared in it and slower when it did not. This effect persisted even when participants were explicitly instructed that circle colour was irrelevant and potentially misleading. Poirier, Gosselin, and Arguin

(2008) investigated the salience of items differing in colour from their surroundings using a visual spread task. Participants viewed a display with a black background consisting of a grid of lines that varied in colour (red or green) and orientation (oblique, left, or right). Brightness within the display also varied, and participants were instructed to adjust the luminance of a section using a mouse until all areas of the display appeared perceptually homogeneous. The results indicated that participants made more adjustments in the regions they perceived as most salient, demonstrating that attention was automatically drawn to areas where lines differed most from their neighbours in colour and orientation. Some studies have investigated whether certain colours in the spectrum are more salient—that is, more capable of eliciting bottom-up attention—than others, but the results remain ambiguous. Wool, Komban, Kremkow, Jansen, Li, Alonso, and Zaidi (2015) employed a subitizing search task in which participants viewed a display composed of many small squares serving as background. Depending on the experimental condition, the background squares consisted of either a blue-yellow or a red-green pair. A variable number of larger squares (one to three, depending on the trial) representing targets appeared on the display. In the blue-yellow condition, target squares were either all yellow or all blue; in the red-green condition, targets were either all red or all green. Participants were instructed to identify, as quickly and accurately as possible, the number of target squares present. The authors hypothesised that if a target of a given colour is more salient than its background, bottom-up attention would be automatically directed to it, resulting in faster and more accurate responses. Results showed that yellow targets were more salient than blue targets, as participants identified yellow targets more quickly and accurately. No significant difference in saliency was observed between red and green targets. In a paradigm similar to the previous one, Etchebehere and Fedorovskaya (2017) present participants with a display composed of a variable number of circles of 18 different hues, drawn from four basic colours (i.e., red, green, blue, and yellow), which vary in intensity. The task is to report the number of circles that appear in each presentation. The blue and red items were found to be the most salient (i.e., they were reported the most times), while the yellow items were found to be the least likely to be reported. No significant difference was found in the number of reports between the colours red and green.

Overall, these studies converge on the idea that differences in colour between an item and its surrounding elements generate perceptual salience, automatically capturing bottom-up attention. The evidence indicates that larger contrasts between a target and its distractors facilitate rapid detection, whereas increasing similarity shifts processing toward a slower, serial search. Furthermore, certain colours within the spectrum appear to differ in their intrinsic salience, although results are somewhat inconsistent across paradigms: yellow and red frequently emerge as highly salient, whereas blue and green may be less consistently attention-grabbing depending on the experimental context. Together, these findings highlight that colour contrast is a robust determinant of automatic attentional capture, while specific hue effects may be modulated by task design and background composition.

Luminance is another basic visual feature capable of capturing bottom-up attention. Psychophysical studies have demonstrated that the human visual system can perceive luminance contrasts in a scene rapidly and efficiently. Kamkar, Moghaddam, and Lashgari (2018) emphasise that this ability is ecologically important, as changes in luminance convey critical information about the environment, such as time of day or weather conditions. Turatto and Galfano (2000) found that participants detected a target (a red vertical line) more quickly and accurately when it appeared in the brightest of six grey circles on a dark background. Similarly, Irwin, Colcombe, Kramer, and Hahn (2000) showed that not only the sudden onset of a bright element but also the temporary increase in luminance of an existing element can automatically attract attention. In their experiment, participants fixated on a central asterisk while five grey circles were presented. After 1500 ms, a target appeared in one of the circles. Two critical conditions were tested: (1) Luminance target, where the target's circle increased in luminance from 16 cd/m² to 24 cd/m² while a new distractor appeared; (2) Onset target, where the target appeared suddenly while a preexisting circle temporarily brightened, serving as a distractor. Results showed that in both conditions, response times were slowed, particularly in the Onset target condition, where the brightened distractor briefly captured attention. Pashler, Dobkins, and Huang (2004) further demonstrated that luminance contrast between targets, distractors, and background modulates attentional capture. In a design manipulating background brightness (dark vs. bright), target contrast (high vs. low), and distractor contrast (absent, high, low), they found that: (1) the presence of distractors slowed responses; (2) responses were slower when high-contrast distractors were present alongside low-contrast targets; and (3) increasing distractor contrast generally slowed responses for high-contrast targets but facilitated responses when targets were low-contrast. Finally, Adams (2007) investigated the detection of subtle luminance differences using a display of 16 circles arranged in concentric rings around a central fixation point. Targets differed from distractors in shading gradient, either vertical (brighter at the top) or horizontal (brighter on one side). Participants detected targets rapidly and more efficiently when the shading was vertical, consistent with the natural assumption that light typically comes from above ("light-from-above" effect). These findings indicate that the visual system is tuned to detect luminance differences automatically and quickly, reflecting both ecological constraints and perceptual efficiency.

Collectively, these studies demonstrate that luminance differences are a powerful determinant of bottom-up visual attention. Items that are brighter or darker than their surroundings automatically attract attention, facilitating rapid detection, whereas distractors with high luminance contrast can slow response times depending on the context. Moreover, the visual system appears to exploit natural lighting assumptions, as evidenced by faster detection of vertical shading gradients. Overall, luminance is a robust cue for attentional capture, operating automatically and efficiently across diverse visual contexts.

5.2. The orientation in the space of visual stimuli

The spatial orientation of a visual stimulus—defined as the alignment of an item vertically, horizontally, or obliquely relative to the general plane of the scene—is another fundamental feature that captures visual attention in a bottom-up manner. Julesz and Bergen (1983) argued that spatial orientation is detected preattentively, automatically, and effortlessly. At this early stage of vision, the goal is not to perceive fully defined shapes but to form an organic representation of the visual configuration. Automatic detection of stimulus orientation facilitates the visual system in defining the boundaries between distinct areas of a scene, thereby aiding in the construction and understanding of the perceptual environment (Dakin & Watt, 1997). Evidence for this process comes from various psychophysical texture segmentation experiments.

Julesz and Bergen (1983) demonstrated that participants could rapidly recognise a silhouette (e.g., a square) composed of elongated R-shaped patterns oriented uniformly to the right, embedded in a background of Rs with varied orientations. Attention was drawn in a bottom-up manner to the region in which the Rs shared the same orientation, enabling the quick detection of the silhouette. Similarly, Dakin and Watt (1997) employed a texture segmentation task using Gabor stimuli (sinusoidal gratings enveloped by a Gaussian function, widely used as simplified models of local spatial features such as edges, orientations, and textures in early visual processing) to assess participants' ability to discriminate areas composed of differently oriented items. The results showed that, within 100 ms, participants could both distinguish different regions based on the average orientation of stimulus groups and identify the group with the greatest number of items. These findings confirm that spatial orientation is a feature to which attention is automatically directed, facilitating the division of a scene into distinct segments. Utochkin, Khvostov, and Stakina (2018) extended this work by presenting participants with a briefly displayed screen (200 ms) divided into 64 cells, each containing a line with variable tilt (vertical, horizontal, or ±23°). In the Sharp Condition, neighbouring cells contained lines with maximally different orientations (e.g., nearly vertical next to nearly horizontal), producing sharp local contrasts. In the Smooth Condition, neighbouring cells contained lines with more similar, randomly varied orientations, thereby reducing local orientation contrasts. Participants performed the texture segmentation task more quickly and accurately in the Sharp Condition than in the Smooth Condition. This finding supports the theory that greater differences in spatial orientation among items facilitate the visual system's segmentation of the scene into discrete units automatically detected by attention (Wolfe & Horowitz, 2017).

Visual attention's automatic attraction by an item's spatial orientation is further evidenced by visual search tasks' Rosenholtz (2001) asked participants to search for a horizontal segment among segments with varying orientations under four experimental conditions: (1) Homogeneous, in which all distractors were tilted by 30°; (2) Low variability (A), in which one-third of distractors were tilted by 30° and two-thirds by 50°; (3) High variability, in which one-third of distractors were tilted by 30°, one-third by 50°, and one-third by 70°; and (4) Low variability (B), in which one-third of distractors were tilted by 30° and two-thirds by 70°. Results indicated that participants identified the target most rapidly in the Homogeneous condition, followed by the two Low variability conditions. Performance was poorest in the High variability condition, confirming that attention is automatically drawn to items that differ maximally from surrounding distractors. In contrast, targets similar to distractors are detected less efficiently. Poirier, Gosselin, and Arguin (2008) further tested whether discontinuities in spatial orientation increase stimulus salience and thus attract bottom-up attention. In their visual spread task, participants viewed a black screen displaying bright lines of two colours (red or green) and two orientations (tilted 45° to the right or left), forming a grid. Participants were instructed to detect sections with brightness differences and adjust these areas to create a homogeneous percept. As predicted, attention was first directed to sections with the greatest orientation differences relative to neighbouring lines, indicating that orientation discontinuity drives the rapid allocation of attention. Similarly, Van der Burg, Cass, Theeuwes, and Alais (2015) examined the role of spatial orientation in visual search across multiple trial blocks. Participants searched for a horizontal red line target among 72 distractors varying in orientation (0°, 10°, or 90°) and colour (red, green, or blue). Using a genetically based algorithm, distractor characteristics were progressively modified across blocks, increasing task difficulty. The authors observed that colour and spatial orientation are basic features that guide bottom-up attention. As distractors became increasingly similar in orientation to the target, detection performance slowed, demonstrating the importance of orientation differences in facilitating rapid target identification.

Finally, Alvarez and Oliva (2008) demonstrated that even when visual attention is focused on a specific item, a portion of attention is automatically and involuntarily directed toward the spatial orientation of other items in the scene. In such cases, the visual system may not perceive the precise shapes of unattended objects but still encodes basic features that allow for a global, approximate scene representation. Using a dual-task paradigm, participants viewed a screen displaying eight moving circles, four designated targets and four distractors. Targets and distractors differed in the areas of the screen where they moved (e.g., in some trials, targets moved only in the upper section, and distractors only in the lower section, and vice versa). Participants were instructed to focus exclusively on the movement of the targets while ignoring the distractors. During the trials, all circles disappeared for 200 ms and then reappeared. On reappearance, one item (target or distractor; Single missing item condition) or all four items of a category (targets or distractors; Centroid condition) were removed. Participants were required to indicate the missing item's position in the Single missing item condition or mark the centroid representing the average location of the missing items in the Centroid condition. Accuracy served as the dependent measure. Results indicated that, in the Single missing item condition, participants made significantly fewer errors when identifying a missing target's position than a missing distractor. Indeed, performance in detecting missing targets was above chance, whereas responses for missing distractors did not exceed chance. In the Centroid condition, participants were more accurate in estimating the mean position of targets than distractors, yet performance exceeded chance for both categories. These findings suggest that, even when attention is focused on specific targets, the visual system retains a coarse representation of unattended items, particularly their spatial orientation, through involuntary and automatic allocation of attention to this fundamental feature.

In summary, spatial orientation is a fundamental feature that automatically attracts visual attention and contributes to rapid scene analysis. Across a variety of paradigms—including texture segmentation, visual search, and dual-task studies—research consistently shows that differences in spatial orientation guide attention in a bottom-up manner, facilitate the segregation of objects from distractors, and support the construction of both detailed and global representations of visual scenes (Julesz & Bergen, 1983; Rosenholtz, 2001; Alvarez & Oliva, 2008). Complementary evidence from Wolfe (2001) indicates that spatial orientation can also produce search asymmetries, meaning that targets salient in orientation relative to distractors are located faster than less salient targets. These findings, overall, demonstrate that the human visual system exploits orientation discontinuities to segment and prioritise information efficiently, even when attentional resources are otherwise engaged.

5.3. The shape of visual stimuli: closure, lines' intersection, and the presence of spikes

The shape of a visual stimulus—defined as the set of features that delineates its contours—can also elicit bottom-up attention. Among the basic features constituting shape, those most investigated in psychophysical studies are contour closure, line intersections (or segmentability), and the presence or absence of spiky sections.

Regarding contour closure, proponents of object-based attention theories argue that its primary function is facilitating the identification of discrete objects. Specifically, items with closed contours are more easily perceived as objects, allowing the visual system to segment scenes into figure and background (Kovács & Julesz, 1993; Zhang et al., 2017). Evidence that visual attention is drawn to items with closed contours comes from various contour detection experiments, which can be variants of texture segmentation tasks. In these tasks, participants detect a shape (e.g., a square or circle) hidden among other stimuli in a visual display. Saarinen and Levi (1999) presented participants with eight Gabor stimuli under three experimental conditions: (1) closure without corners, in which Gabor pairs were arranged to form the sides of an implied square without vertices; (2) closure with corners, in which segments joined at vertices to form the corners of an implied square lacking corresponding sides; and (3) lack of closure with corners, in which Gabor stimuli were placed at the corners of an implied square but oriented outward to prevent shape completion. Participants were instructed to detect, as quickly as possible, the presence or absence of a square. Performance was superior—i.e., faster reaction times (RTs) and fewer errors—when Gabor segments facilitated the perception of a closed outline (conditions 1 and 2) compared to when closure was not favoured (condition 3). Similarly, Kovács and Julesz

(1993) showed Gabor stimuli on a dark screen, arranging them to form either a closed curved line or an incompletely closed shape. They found that closed shapes were identified faster and with fewer errors, indicating that visual attention is automatically guided toward stimuli with closed contours. Zhang, Zhu, Ding, Zhou, Hu, and Ma (2009) and Gerhardstein, Tse, Dickerson, Hipp, and Moser (2012) further confirmed this effect. In their studies, participants viewed Gabor stimuli forming either a circle or an S-shaped outline. Reaction times and error rates were lower for the circle than for the S-shape. Gerhardstein et al. (2012) extended this investigation by varying the curvature of the S-shape (22.5°, 25.7°, 30.0°, 36.0°), finding that detection performance decreased as curvature increased, with the worst performance at 36.0°. In another experiment, they controlled for symmetry and uniformity of curvature by presenting Gabor stimuli arranged in paired arcs either delimiting a closed region (concavities facing outward) or not forming a closed region (concavities facing inward). Once again, a closed-contour effect emerged: participants more easily detected shapes when the arrangement created a closed region of space.

Mathes and Fahle (2007) investigated the influence of closed contours on automatic attention by manipulating both the number of elements forming a contour and the contour's smoothness (i.e., the absence of turning points). Their experimental setup was similar to that of Gerhardstein et al. (2012), with segments arranged to form either a closed circular shape or an S-shaped figure. Detection accuracy for these shapes was tested across conditions in which the number of segments forming the contour varied (e.g., the circular shape consisted of 7, 8, 9, or 12 segments, depending on the condition). The results indicated that performance improved when segments formed a perceptually closed circular shape compared to an S-shaped, non-closed figure, and that accuracy increased as the number of segments forming the contour grew. This finding supports the idea, previously proposed by Li and Gilbert (2002), that the salience of a contour is positively related to the number of elements defining it. In contrast, performance declined significantly when a turning point was present, as in S-shaped outlines. Zhang, Wan, Jin, and Li (2017) further argued that it is "perceptual closure," rather than strictly "geometric closure," that drives automatic visual attention. They proposed that even fragments of a closed contour can elicit the perception of a visual object, provided the configuration suggests that missing sections are occluded rather than absent. This aligns with natural visual processing, in which the human visual system can perceive objects even when other objects block portions of their contours. To test this, the authors used a modified version of Egly, Driver, and Rafal's (1994) paradigm, presenting participants with two side-by-side rectangles partially occluded by a mosaic bar. In one condition, the depth of the rectangle segments was offset from the depth of the mosaic bar, preventing perceptual closure. Under these circumstances, the impression of two distinct, closed objects was not generated, and the object-based advantage—where visual attention is automatically drawn to a perceived object—was abolished.

These findings indicate that visual attention is automatically attracted to shapes with closed or perceptually completed contours. Both the number and smoothness of contour elements enhance this effect, and even partial or occluded contours can elicit attentional capture when the visual system infers a complete object. Thus, whether geometric or perceptual, closure serves as a fundamental feature guiding bottom-up attentional processes.

Two other basic features of a stimulating configuration capable of attracting visual attention in a bottom-up manner have been studied in the literature. They concern line segments and their relationships, particularly line intersections (i.e., segments that cross at an intersection point) and line terminators (i.e., ends of segments). It is believed these features facilitate the shape's definition of a visual stimulus and, hence, the process of percept segmentation into figure and background. Julesz and Bergen (1983), within the feature-based visual attention paradigm, stated that the visual system, in the early stage of vision, can distinguish only a few basic shapes, that the authors called textons (i.e., elongated shapes such as rectangles, ellipses or line segments), and visual attention quickly and automatically is attracted to textons' colour, orientation in space, terminators, and intersection. Regarding the intersection between segments, the authors, using a texture segmentation task, have shown that the human eye discriminates a set of + (i.e., crosses) among a set of Ls quickly and easily, but not a set of Ts among a set of Ls. This phenomenon happens because, in the case of the crosses, the textons have the salient feature of intersection which allows a rapid distinction of crosses from Ls. In contrast, Ls and Ts do not have this basic feature capable of activating a bottom-up visual attention process; thus, to discriminate between Ts and Ls, it is necessary to use focused attention.

Julesz and Bergen (1983) also brought various evidence to support the role of line terminators in eliciting automatic attention. In a texture segmentation task, participants must distinguish between two types of items composed of three segments identical in length, width, and orientation in space; they differ in how their terminators are arranged. All the segments are connected, forming the shapes of small triangles (i.e., no terminators are present), or the segments are connected only at one point so that three open ends (i.e., three terminators) remain. The study has shown that segments with three terminators stood out against the background of small triangles; i.e., visual attention was immediately and automatically drawn to the terminators, making those kinds of stimuli more salient than small triangles. It has also been shown that the texture segmentation task can be performed easily even when segments converge at a single vertex, generating five terminators. However, in another experiment, an image composed of the letter "S" and the number "10" was used. Although these stimuli look very different, they both contain the same number of line endings, or terminators—two in each case (the "S" has one end at the top and one at the bottom, while the "1" in "10" has two endpoints and the "0" is closed). Because the number of terminators is identical, juxtaposing these items makes the texture segmentation task much more difficult. Treisman and Gormican (1988) took up the studies of Julesz and Bergen (1983) concerning line terminators and intersections, but they did not replicate the results. They compared pairs of stimuli where one stimulus was considered salient for the presence of the basic feature of line terminators or intersections, and the other stimulus did not have these features. In a visual search task, on one trial, one stimulus in the pair had the role of the target, and the other was a distractor; on the subsequent trial, the opposite occurred. The hypothesis was as follows: if the basic feature investigated can elicit bottom-up attention in the task, when the item with the salient feature is the target, as the number of distractors increases, response times will not increase because the item will pop up among the other stimuli. The stimuli used are as follows: to study line intersections, crosses (i.e., two segments 13 mm in length that intersect at their midpoint) are compared with two segments placed vertically and horizontally, respectively, and adjacent at one point but not intersecting. For line terminators, two segments joined at one point to form a right angle (2 terminators), and two segments perpendicular to each other but not joined, with a small gap at the point of intersection (4 terminators), are compared. The results showed that neither the line intersections nor the line terminators elicited bottom-up visual attention: in the trials, the time for target detection increased significantly as the number of distractors increased, which indicates that a serial search was in progress. Wolf and Di Mase (2003) also do not think line intersection is a basic feature capable of eliciting bottom-up attention. They have argued that symmetry and the number of line terminators, rather than line intersection, in Julesz and Bergen's (1983) experiment, where crosses and L-shapes were compared, had an important role in visual search processes. In addition to intersection, cross and L-shaped items also differ in the number of terminators (i.e., a cross has four terminators, an L only two) and symmetry (i.e., the cross is a symmetrical figure, the L is not).

To test this hypothesis, Wolfe and Di Mase (2003) created an experimental setup in which they modified the shape of a cross: one of the two horizontal arms was shifted downward along the vertical axis, producing a stimulus composed of four separate terminators—no longer symmetrical and lacking an intersection. In a visual search task, six experimental conditions were tested. Four of these replicated Julesz and Bergen's (1983) study, while two were critical for assessing the role of line intersections. In the first critical condition, participants searched for a standard cross among items without intersections. In the second, they searched for a modified cross—composed of four separate line segments resembling a cross but without intersections—among similar non-intersecting crosses. Both searches were highly inefficient, showing longer reaction times than the classic search for a T among Ls or an L among Ts. These results led the authors to conclude that intersections alone cannot automatically capture bottom-up attention.

Still regarding the basic features of line intersection, Cole, Gellatly, and Blurton (2001) and Burnham and Neely (2007) obtained results in contrast with Wolfe and Di Mase (2003) and in line with Julesz and Bergen (1983). Cole, Gellatly, and Blurton (2001) have found the corner enhancement effect, i.e., when a new object appears in the visual scene, attention is automatically directed to the corners of the object, where there is an intersection between lines. They have conducted nine experiments based on the pre-cueing paradigm. The experimental apparatus is composed as follows: on a display, a central cross as a fixation point appears, after 1,500 ms, a rectangle appears, and after 100 ms more, a small dot with low brightness contrast, with the role of the target, appears. The dot can have different positions relative to the rectangle. The results of the experiments showed that participants were faster in detecting the target when the dot appeared in an adjacent position to the sides of the rectangle (i.e., where there is an intersection of lines), compared with when the dot appeared near one of the long sides of the rectangle. The authors obtained the same results also controlling for the target's contrast in brightness and for different silhouettes of the shape that appeared on the screen. Burnham and Neely (2007) came to similar conclusions. They presented a display with two lines intersected at one point (i.e., cuing display). After a short time, the two lines disappeared, and seven different letters appeared. The task consisted of indicating whether a target (i.e., a letter R or A) was present among the other different letters that served as distractors. Different experimental conditions were provided: 1. Intersection: the target was positioned where the two lines intersected in the previous cuing display; 2. Line-Only: the target was positioned on one of the two lines that had previously appeared in the cuing display, but not in the lines' intersection; 3. Uncued Adjacent: the target was adjacent (i.e., had maximum proximity) to the lines' intersection in the precedent cuing display; 4. Uncued Close: the target was close to the lines' intersection but not adjacent to it; 5. Uncued Far: there was maximum distance between the target and the intersection of the lines. The results showed that attention was automatically attracted to the intersection between lines; as hypothesised, the RTs for target detection were shorter in the Intersection condition, followed by the Line-Only and Uncued conditions.

Finally, Huang (2020) employed a texture segmentation task in which participants were asked, across several trials, to detect as quickly as possible a rectangle composed of one of two types of stimuli in a pair and indicate whether it was oriented vertically or horizontally relative to the overall scene. The study compared 14 different basic features of the items, including closure, line intersection, concavity, convexity, discontinuity and continuity of parts, elongated shapes, curved edges, straight edges, and combinations of curved and straight edges. Pairwise comparisons revealed that three features were extracted rapidly and in parallel through a bottom-up visual attention mechanism. Items with lines intersecting at a point (segmentability) were more salient than items without intersections; closed and concave items (compactness) were more salient than items lacking closure; and items with sharp parts, resulting from line terminators (spikiness), were more salient than items without sharp parts. These findings support the hypothesis that the human visual system automatically directs attention to basic features that enhance the perception of object contours and silhouettes. In summary, the reviewed studies indicate that certain shape features consistently elicit bottom-up visual attention. Closed or perceptually completed contours enhance object segmentation and attract attention automatically, with salience increasing as the number and smoothness of contour elements grow. Line intersections and terminators can also guide attention, though their effect depends on contextual factors such as symmetry, spatial arrangement, and proximity to other features. Overall, the human visual system, according to Huang (2020), prioritizes features that define object contours and silhouettes, with the key features driving this process being the presence of close lines (i.e., compactness), the presence of line terminators (i.e., spikiness), and the presence of lines' intersection (i.e., segmentability).

6. Discussion and conclusion

The branch of psychology that studies visual perception has sought to understand how the human visual system processes stimuli from the physical world to generate the conscious vision of discrete objects. Various pieces of evidence have shown that automatic and involuntary visual attention plays an important role in the early stage of vision. In fact, this type of attention is bottom-up attracted to some basic features of the physical stimuli, the combination of which enables the construction of visual objects at a more advanced stage of vision (Treisman & Gelade, 1980; Pramod & Arun, 2014; Kamkar, Moghaddam and Lashgari, 2018).

The relationship between the basic features of a physical stimulus and automatic and involuntary visual attention has been investigated by various psychophysical studies, which, although based on different theories, have often arrived at similar conclusions. Studies based on the Gestalt School start from the theory that, when faced with a stimulating configuration of the physical world, visual attention is immediately, spontaneously, and effortlessly directed toward certain basic relationships between elementary physical items. The identification of these basic relations, in turn, allows the activation of two basic processes, which are grouping (i.e., the clustering of similar stimuli that facilitates the perception of discrete objects) and the segmentation of the image into figures (i.e., defined and foreground elements) and background (i.e., undefined elements in the background). Following Gestalt's ideas, two orders of experimental evidence show this, and precisely:

a) even when the experimental subject's visual attention is focused on a specific task, a residual portion of attention is drawn, in a bottom-up manner, to the basic relations between the items that are present in the stimulating configuration, and this causes, at the perceptual level, "proto-objects" to be generated that, often below the subject's threshold of awareness, are capable of conditioning the performance. Various dual-task studies have shown this, see for example the work of Moore and Egeth (1997), Russel and Driever (2005), Lamy, Segal and Ruderman (2006), Kimchi and Peterson (2008), and Kimchi, Razpurker and Apefeld (2004);

b) when in a stimulating configuration, "proto-objects" are generated via the basic relations between items identified by Gestalt; these "proto-objects" automatically attract visual attention, even when they have no relation to the task that has been assigned to the experimental subject. In this direction goes the evidence brought by Duncan (1984), Baylis and Driver (1993); Egly, Driver and Rafal (1994); Kramer, Weber and Wotzon (1997), Macquistan (1997); Behrmann, Zemel and Mozer (1998), Chen (2000), Pratt and Sekuler

(2001), Marino and Scholl (2005), Chen and Cave (2006), Hecht and Vecera (2007); Yeshurun, Kimchi, Sha'shoua and Carmel (2009), Kerzel, Born and Schonhammer (2012), Kimchi, Yeshurun, Spehar and Pinker (2015).

Regarding the basic relationships between elementary items capable of attracting involuntary visual attention in a bottom-up manner, studies drawing on Gestalt's theories have identified:

a) *items' similarity* (Baylis & Driver, 1993; Moore & Egeth, 1997; Chen, 2000; Cahn & Chua, 2003; Schulz & Sanocki, 2003; Han, 2004; Kimchi, Rrazpurker-Apafeld, 2004; Lamy, Segal, and Ruderman, 2006; Russel & Driver, 2006; Razpurker-Apfeld & Kimchi, 2007; Hecht & Vecera, 2007; Kerzel, Born, and Schönhammer, 2012);

b) *items' proximity* (Duncan,1984; Baylis and Driver, 1993; Vecera and Farah, 1994; Egly, Driver and Rafal, 1994; Kurylo, 1997; Kramer, Weber and Wotzon, 1997; Macquistan, 1997; Moore, Yantis and Vaughan, 1998; Chen, 1998; Behrmann, Zemel and Mozer, 1998; Chen, 2000; Pratt and Sekuler, 2001; Kimchi, Rrazpurker-Apafeld, 2004; Han, 2004; Drummond and Shomstein, 2010; Kerzel, Born and Schoenhammer, 2012);

c) *items' good continuation or collinearity* (Duncan, 1984; Vecera & Farah, 1994; Egly, Driver and Rafal, 1994; Kurylo, 1997; Kramer, Weber and Wotzon, 1997; Macquistan, 1997; Behrmann, Zemel and Mozer, 1998; Chen, 1998; Moore, Yantis and Vaughan, 1998; Pratt & Sekuler, 2001; Chen & Cave, 2006; Kimchi, Yeshurun and Cohen-Savransky, 2007; Yeshurun, Kimchi, Sha'shoua and Carmel, 2009; Richard, Lee and Vecera, 2008; Drummond & Shomstein, 2010; Kimchi, Yeshurun, Spehar and Pirkner, 2016);

d) *items' symmetry* (Kimchi, Yeshurun and Cohen-Savransky, 2007; Yeshurun, Kimchi, Sha'shoua and Carmel, 2009; Kimchi, Yeshurun, Spehar and Pirkner, 2016).

Instead, with regard to the basic characteristics of the items, capable of generating the relationships described above, studies based on Gestalt's theories have identified:

a) *items' color* (Baylis & Driver, 1993; Moore and Egeth, 1997; Chen, 2000; Schulz & Sanocki, 2003; Kimchi, Razpurker and Apefeld, 2004; Russel and Driver, 2006; Hecht and Vecera, 2007; Kerzel, Born and Schönhammer, 2012);

b) *items' luminance* (Lamy, Segal and Ruderman, 2006; Razpurker-Apfeld & Kimchi, 2007; Hecht & Vecera, 2007),

c) *item's size/dimension* (Pratt & Sekuler, 2001; Chan & Chua, 2003; Han, 2004; Kimchi, Yeshurun and Cohen-Savransky, 2007; Yeshurun, Kimchi, Sha'shoua and Carmel, 2009; Kimchi, Yeshurun, Spehar and Pirkner, 2016).

d) *items with closed contours* (Duncan, 1984; Vecera & Farah, 1994; Egly, Driver, and Rafal, 1994; Kramer, Weber, and Wotzon, 1997; Macquistan, 1997; Behrmann, Zemel, and Mozer, 1998; Moore, Yantis and Vaughan, 1998; Chen, 1998; Pratt & Sekuler, 2001; Marino & Scholl, 2005; Chen & Cave, 2006; Kimchi, Yeshurun and Cohen-Savransky, 2007; Kimchi & Peterson, 2008; Richard, Lee and Vecera, 2008; Drummond & Shomstein, 2010; Kerzel, Born and Schönhammer, 2012; Kimchi, Yeshurun, Spehar and Pirkner, 2016).

Turning to the theories that have described the process of visual search for a stimulus within a stimulating configuration, they state that, in the early stage of vision, the visual system is not capable of analyzing all the stimuli it receives from the outside world, so a process is activated by virtue of which visual attention, in an automatic and involuntary manner, is drawn to specific items' salient basic features. These salient features are processed quickly and in parallel by the visual system, in order to generate "proto-objects" (i.e., to get a global and approximate view of the percept). Then, in a more advanced stage of vision, voluntary attention will be directed at the "proto-objects", so as to arrive at a detailed perception of the image (Treisman & Gelade, 1980; Treisman and Gormican, 1988; Wolfe, 1994; Wolfe & Gray, 2007; Wolfe & Horowitz, 2017; Wolfe, 2021). The confirmation of the existence of items' salient basic features, capable of attracting visual attention in a bottom-up manner, is provided by pieces of evidence from both visual search tasks and texture segmentation tasks. In the former, in fact, it is shown that if, in a set of stimuli, a target has a salient basic feature, target search time does not increase as the number of distractors increases, because attention is immediately drawn to the salient feature; in the latter, if a group of items possesses a salient basic feature, experimental participants are able to quickly and effortlessly identify a figure emerging from a background within a stimulating configuration. According to these studies, the basic features of an item capable of attracting attention in an automatic manner are:

a) *items' colour*. The colour contrast between items attracts attention (Carter, 1982; Moralgia, Maloney, Fekete and Al-Basi, 1989; Turatto & Galfano, 2000; Poirier, Gosselin and Arguin, 2008) and this happens even if experimental participants are explicitly told that the color dimension is not useful, or is even detrimental, to the task (Turatto and Galfano, 2001). The attentional mechanism that directs visual attention toward the color of the items, thus, is difficult to inhibit. Some studies have also tried to understand whether, within the color spectrum, there are some colors that are more salient than others but there are no unambiguous results. The perceptual experience of color has traditionally been exemplified in two antithetical pairs: red-green and blue-yellow. Wool, Komban, Kremkow Jansen, Li, Alonso, and Zaidi (2015) found that in the blue-yellow dimension, yellow stimuli are more salient than blue stimuli, while in the red-green dimension, no significant differences were found in this regard. Etchenbehere and Fedorovskaya (2017) found that red turns out to be the most salient color, while blue is the least salient. Mullen and Kingdom (2002) pointed out that the human visual system appears to be more sensitive to color contrasts in the red-green system than in the blue-yellow system, as the foveal area, which is responsible for the visual acuity, is specialized in detecting variations in the red-green color spectrum;

b) *items' luminance*. This item's feature also attracts attention in a bottom-up manner (Irwin, Colcombe, Kramer and Hahn, 2000; Turatto and Galfano, 2000; Pashler, Dobkins and Huang, 2004). In addition, the light-from-above effect, identified by Adams (2007), shows that the visual system, by automatically directing attention to contrasts in luminance, is able to perceive the shading gradient of an element, information that allows one to understand the way an object is illuminated (i.e., whether from above, below or to the side) and, consequently, its shape and position in the space. Irwin, Colcombe, Kramer, and Hahn (2000) have found that, within a stimulating configuration, visual attention is automatically directed not only toward a new light stimulus that suddenly appears but also toward an already present stimulus that increases its luminance level. Pashler, Dobkins, and Huang (2004) have shown that, if there is a brightness contrast between items, attention automatically turns to the brighter ones; participants, however, are able to inhibit this mechanism if they understand that turning attention to the brighter stimuli is detrimental to the visual search task;

c) *Items' orientation in the space*. There are various pieces of evidence that visual attention quickly and automatically turns to the detection of the stimuli's spatial orientation, in order to create an approximate and global representation of the scene. In fact, the item's dimension of spatial orientation, at an early and pre-attentive stage of vision, facilitates stimulus grouping operations and scene segmentation tasks, promoting the perception of discrete objects with their relative shape (Treisman and Gelade, 1980; Julesz and Bergen, 1983; Dakin and Watt, 1997; Wolfe, 2001; Poirier et al., 2008; Alvarez and Oliva, 2008). Poirier, Gosselin and Arguin (2008), Utochkin and Yurevich (2016), and Utochkin, Khvostov and Stakina (2018) have shown that a visual stimulus is salient (i.e., it attracts visual attention automatically) when it differs in its orientation in the space from the distractors surrounding it; on the other hand, it isn't salient when it shares the same spatial orientation with the distractors. Saarinen and Levi (1999) also pointed out that visual attention is more easily directed toward the parts of the stimulating configuration that share the same spatial orientation as the overall scene set-up, rather than toward stimuli that have a spatial orientation not in line with the overall scene orientation;

d) *Items with closed contours, lines' intersection, and presence of spikes* (the latter determined by the presence or absence of line terminators). These basic features facilitate the definition of the shape of a visual object and therefore automatically attract attention. A stimulus with closed contours (i.e., an arrangement of items capable of forming a closed contour that delimits a portion of space within it) draws automatic visual attention to itself (Kavacks & Julesz, 1993; Marino & Scholl, 2005; Gerhardstein et al., 2012; Zhang et al., 2017). The perception of closure is facilitated by the presence of collinear or near collinear items (Kavacs & Julesz, 1993), which, according to Gerhardstein et al. (2012), is a factor that is not coincident with the Gestalt concept of good continuation. Furthermore, the ease in perceiving the closure of a contour improves as the number of segments forming the contour increases (Mathes & Fahle, 2007; Gerhardstein et al., 2012) and worsens significantly if there is the presence of a turning point (Mathes & Fahle, 2007). In addition, the effect of "perceptual closure" has also been shown to attract visual attention. This phenomenon is generated when the visual system is able to derive the impression of closure by integrating "fragments" of contour, and it happens when the set-up of the stimulating configuration allows for the inference that parts of the contour are partially occluded due to the superimposition of other objects (Zhang et al., 2017). Visual attention also seems to be automatically attracted by lines intersection or segmentability, i.e., the presence of, at least, one point of intersection between two segments (Bergen & Julesz, 1983; Burnham & Neely, 2007; Cole, Gellatly and Blurton, 2001) and by spikes, generated by the presence of lines terminators (Bergen & Julesz, 1983; Wolf & Di Mase, 2003; Huang, 2020). However, there are also contrary pieces of evidence on the power of these basic features to elicit bottom-up visual attention (Treisman & Gormican, 1988; Wolfe & Di Mase, 2003). The difference in results may depend on the different experimental apparatuses used. Apparatuses involving texture segmentation tasks might be more sensitive in detecting bottom-up attentional processes than visual search tasks.

In conclusion, the reviewed literature, drawing from different theoretical approaches, converges on the finding that, at an early stage of vision, automatic and involuntary visual attention processes are activated, enabling the visual system to rapidly detect basic features of physical items—such as colour, luminance, orientation in space, contour closure, line intersections, and the presence of spikes—as well as elementary relationships between items, including similarity, proximity, good continuation or collinearity, and symmetry. These processes allow for the formation of an initial rough representation of the scene, or "proto-objects," that stand out against an undefined background. At a subsequent vision stage, voluntary attention can then focus on specific parts of the scene, leading to a detailed and precise perceptual representation.

Analyses of visual attention mechanisms reveal that studies based on visual search theories tend to emphasise single-item features (e.g., colour, brightness, orientation). In contrast, studies grounded in Gestalt theories focus more on the relationships between items (e.g., proximity, similarity, collinearity). Closure emerges as a basic feature identified by both approaches. Thus, within any stimulating configuration, single-item features and elementary inter-item relationships can elicit bottom-up attention and facilitate rapid scene perception. Consistent with early Gestalt insights, configurations in which relationships between items are ambiguous may produce perceptual effects such as reversible or ambiguous images (e.g., Rubin's figure-ground inversion, Boring's ambiguous images).

Understanding the basic features that attract automatic attention has important implications for psychology. Since "proto-objects" form the foundation of meaningful perceptual representations, highlighting these features can inform applied domains such as advertising, to create clear and attention-grabbing visuals, or education, to optimise text layouts and improve readability. Environmental psychology, particularly the study of restorative environments, also benefits from these insights. Evidence indicates that scenes, especially natural ones, can facilitate cognitive functioning and recovery from attentional fatigue (Hartig, Book, Garvill, Olsson, & Garling, 1996; Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998; Purcell, Peron, & Berto, 2001; Staats, Kieviet, & Hartig, 2003). While these restorative effects have traditionally been linked to higher-level dimensions such as fascination or coherence (as identified by ART), emerging research suggests that they are underpinned by basic-level visual features capable of automatically engaging attention (Kardan, Demiralp, Hout et al., 2015; Celikors & Wells, 2022; Oliva & Torralba, 2001; Green & Oliva, 2009). Our review indicates that features identified in vision science—colour, luminance, orientation, motion, shape, and symmetry—provide a perceptual foundation for the mechanisms hypothesised by Attention Restoration Theory. In natural environments, these features occur in ways that capture attention effortlessly: green and blue hues attract attention without being intrusive, brightness and orientation variations structure the scene coherently, curved and symmetrical shapes are efficiently processed, and smooth motion (e.g., flowing water, swaying foliage) sustains "soft fascination". Therefore, restorative settings may be where preattentive visual features are abundant and harmoniously organised, offering effortless engagement while minimising cognitive load.

These findings also have practical implications for architectural and environmental design. If specific visual properties reliably support automatic attention, they can be intentionally incorporated into restorative spaces. Biophilic Design, for example, emphasises natural light, greenery, views of nature, water, and natural materials, all of which engage bottom-up attention mechanisms posited by ART (Bolten & Barbiero, 2020; Pasini et al., 2021). A detailed understanding of these features can guide the construction of built environments that maximise cognitive restoration, such as schools, where innovative layouts enhance learning (Stadler-Altmann & Hilger, 2018; Weyland & Galletti, 2018), or workplaces designed to support employee well-being and recovery.

Tab. 1: Experimental apparatus and characteristics of the 53 selected studies					
	Author (Year)	**Experimental Design**	**No. Participants**	**Participants characteristics**	**Basic Features considered**
1	Adams (2007).	Visual search task	Exp. 1= 27	Adults	Item's luminance
2	Alvarez and Oliva (2008)	Dual-task studies	Exp. 1 = 8 Exp. 2= 8 Exp. 3= 8	Undergraduate students that have been paid for their participation in the experiment	Item's spatial orientation
3	Baylis and Driver (1993)	"Flankers task" (Eriksen and Eriksen, 1974)	Exp 1= 10 Exp 2= 20	Undergraduate Students	Proximity and color similarity between items
4	Behrmann, Zemel, and Mozer (1998)	Duncan's (1984) "overlapping objects" task	Exp 1= 9 Exp 2= 5 Exp 3= 29	Undergraduate Students	Proximity, good continuation between items and closure
5	Burnham e Neely (2007)	Pre-cueing paradigm	Exp. 1= 20 Exp. 2= 22	Undergraduate students	Item's intersection
6	Carter (1982)	Visual search task	Exp 1= 212	Undergraduate Students	Item's color
7	Chan and Chua (2003)	Dual-task study	Exp. 1= 14	Undergraduate Students	Similarity in items' dymension
8	Chen (1998)	Spatial pre-cueing paradigm	Exp 1= 8 Exp 2= 8 Exp 3= 8 Exp 4= 8	Undergraduate Students that were paid for the experiment	Proximity, good continuation between items and closure
9	Chen (2000)	"Flankers task" (Eriksen and Eriksen, 1974)	Exp 1= 16 Exp 2= 15	Undergraduate Students	Proximity and color similarity between items
10	Chen and Cave (2006)	"Flankers task" (Eriksen and Eriksen, 1974)	Exp 1= 16 Exp 2= 16	Undergraduate Students	Closure and good continuation between items
11	Cole, Gellatly, and Blurton (2001)	Pre-cueing paradigm	Exp. 1= 12 Exp. 2= 10 Exp. 3= 14 Exp. 4= 12 Exp. 5= 12 Exp. 6= 11 Exp. 7= 14	Adults	Item's intersection
12	Dakin and Watt (1997).	Texture segmentation	Exp.1= 6 Exp. 2= 6	Adults	Item's spatial orientation
13	Drummond and Shomstein (2010).	Spatial pre-cueing paradigm	Exp 1= 46	Undergraduate Students	Proximity, good continuation between items and closure
14	Egly, Driver, and Rafal (1994)	Spatial pre-cueing paradigm	Exp 1= 15	Undergraduate Students	Proximity, good continuation

					between items and closure
15	Etchebehere and Fedorovskaya (2017)	Visual search task	Exp 1= 12	Adults	Item’s color
16	Gerhardstein, Tse, Dickerson, Hipp, and Moser (2012)	Texture segmentation (contours detection task)	Exp. 1= 9 Exp. 2= 7 Exp. 3= 14	Undergraduate students	Item’s closure
17	Han (2004)	Texture segmentation	Exp. 1= 14	Adults	Item’s proximity and similarity
18	Hecht and Vecera (2007).	Spatial pre-cueing paradigm	Exp 1= 21 Exp 2= 22 Exp 3= 21 Exp 4= 24 Exp 5= 21	Undergraduate Students	Similarity in color and luminance between items
19	Huang (2020)	Texture segmentation	Exp. 1= 200	Undergraduate students	Item’s closure, line terminators and line segmentation
20	Irwin, Colcombe, Kramer, and Hahn (2000)	Visual search task	Exp. 1= 12 Exp. 2= 12	Adults	Item’s luminance
21	Kerzel, Born and Schönhammer (2012)	Dual-task study	Exp 1= 16 Exp 2= 20 Exp 3= 20	Undergraduate Students	Proximity and similarity in item’s color, and closure
22	Kimchi and Peterson (2008)	Change detection task	Exp. 1= 47	Undergraduate Students	Concavity/ convexity
23	Kimchi, Razpurker and Apefeld (2004)	Change detection task	Exp 1= 14	Undergraduate Students	Similarity in items’ color and proximity
24	Kimchi, Yeshurun and Cohen-Savransky (2007)	Dual-task study	Exp 1= 14 Exp 2 and 3= 38	Adults	Collinearity and symmetry between items and closure
25	Kimchi, Yeshurun, Spehar and Pirkner (2016).	Dual-task study	Exp 1/a=14 Exp 1/b= 15 Exp 2/a= 16 Exp 2/b= 14 Exp 2/c= 15 Exp 3/a= 12 Exp 3/b= 12 Exp 3/c= 12	Adults	Good continuation and symmetry between items, and closure
26	Kovacs and Julesz (1993)	Texture segmentation (contours detection task)	Exp. 1= 18	Adults	Item’s closure
27	Kramer, Weber, and Wotzon (1997)	Duncan's (1984) "overlapping objects" task	Exp 1= 24	Undergraduate Students	Proximity, good continuation between items and closure
28	Kurylo (1997)	Texture segmentation	Exp.1= 9	Adults	Item’s proximity and good continuation

29	Lamy, Segal and Ruderman (2006)	Change detection task	Exp 1= 10 Exp 2= 16 Exp 3= 10	Undergraduate Students	Similarity in items' brightness
30	Macquistan (1997).	Spatial pre-cueing paradigm	Exp 1= 94	Adults	Proximity, good continuation between items and closure
31	Marino and Scholl (2005)	Spatial pre-cueing paradigm	Exp 1= 45	Undergraduate Students	Closure
32	Mathes and Fahle (2007)	Texture segmentation (contours detection task)	Exp. 1= 13 Exp. 2= 8	Undergraduate students	Item's closure
33	Moore and Egeth (1997)	Dual-task study	Exp 1= 20 Exp 2= 20 Exp 3= 20	Undergraduate Students	Similarity in items' color
34	Moore, Yantis and Vaughan (1998)	Spatial pre-cueing paradigm	Exp 1= 17 Exp 2= 16	Young adults	Proximity, good continuation between items and closure
35	Moraglia, Maloney, Fekete, and Al-Basi (1989)	Visual search task	Exp 1= 5 Exp 2= 5	Adults	Item's color
36	Pashler, Dobkins, and Huang (2004)	Visual search task	Exp. 1= 18 Exp. 3= 18	Undergraduate Students	Item's luminance
37	Poirier, Gosselin, and Arguin (2008)	Visual search task (visual spread task)	Exp 1= 7	Undergraduate Students	Item's color and spatial orientation
38	Pratt and Sekuler (2001)	Spatial pre-cueing paradigm	Exp 1= 8 Exp 2= 8	Undergraduate Students	Proximity, good continuation between items and closure
39	Richard, Lee and Vecera (2008)	"Flankers task" (Eriksen and Eriksen, 1974)	Exp 1= 20 Exp 2= 12 Exp 3= 20 Exp 4= 20	Undergraduate Students	Closure and good continuation between items
40	Rosenholtz, R. (2001)	Visual search	Exp. 1= 4 Exp. 2= 4	Adults	Item's spatial orientation
41	Russel and Driver (2006)	Change detection task	Exp 1= 25 Exp 2= 28 Exp 3= 24 Exp 4= 20 Exp 5= 28	Adults that were paid for the participation	Similarity in items' color
44	Saarinen and Levi (1999)	Texture segmentation (contours detection task)	Exp. 1=12	Adults	Item's closure
43	Treisman and Gormican (1988)	Visual Search task	Exp. 1= 75	Undergraduate students that have been paid for their participation in the experiment	Item's intersections and line terminators
44	Turatto and Galfano (2000)	Visual search task	Exp 1= 12	Undergraduate Students	Item's color and luminance

45	Turatto and Galfano (2001)	Visual search task	Exp 1= 15 Exp 2/a= 12 Exp 2/b= 12	Undergraduate Students	Item's color
46	Utochkin, Khvostov and Stakina (2018)	Texture segmentation	Exp.1= 5 Exp. 2= 21	Adults Undergraduate Students	Item's spatial orientation
47	Van der Burg, Cass, Theeuwes, and Alais (2015)	Visual search using a "genetic algorithm"	Exp. 1= 8 Exp. 2/a= 27 Exp. 2/b= 14	Undergraduate students that have been paid for their participation in the experiment	Item's color and spatial orientation
48	Vecera and Farah (1994)	Duncan's (1984) "overlapping objects" task	Exp 1= 25	Undergraduate Students	Proximity, good continuation between items and closure
49	Wolf and Di Mase (2003)	Visual Search task	Exp. 1= 13	Adults	Item's intersections and line terminators
50	Wool, Komban, Kremkow, Jansen, Li, Alonso, and Zaidi (2015)	Visual subitizing search task	Exp 1= 7	Adults	Item's color
51	Yeshurun, Kimchi, Sha'shoua and Carmel (2009)	Dual-task study	Exp 1= 9 Exp 2= 8	Adults	Collinearity and symmetry between items, and closure
52	Zhang, Wan, Jin, and Li (2017)	Spatial pre-cueing paradigm	Exp. 1= 24	Undergraduate students	Item's closure
53	Zhang, Zhu, Ding, Zhou, Hu, and Ma (2009)	Texture segmentation (contours detection task)	Exp. 1= 12	Undergraduate students	Item's closure

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CONTRIBUTION 2:
THE EFFECTS OF THE BASIC GLOBAL PROPERTIES OF A SCENE ON THE PERCEPTION OF RESTORATIVENESS: AN EXPLORATORY STUDY

ABSTRACT

When we look at a scene, the Scene Centered Approach states that some Basic Global Properties (BGPs) of the image immediately attract our attention and guide us in meaning attribution. According to Attention Restoration Theory, images with features that automatically attract our attention generate a sense of restorativeness. To investigate how BGPs are related to Perceived Restorativeness (PR), we measured six BGPs (openness, depth, expansion, transience, concealment, and navigability) and four dimensions of PR (fascination, coherence, being away, and scope) of eight natural images (four with high and four with low restorativeness previously measured) considering two different measurement methods (single image presentation with 7-point scale vs pairwise presentation with dichotomic scale). Some Mixed Linear Models were tested to verify if BGPs predicted PR levels of the considered images. The results showed the direct effects of BGPs on the four PR dimensions. In addition, some interaction effects between BGPs in determining PR were found. Practical implications of the study for Environmental Psychology, particularly in designing restorative physical environments, will be discussed.

Introduction

Literature has shown that contact with certain physical environments elicits in humans a sense of restorativeness that leads to benefits in the emotional realm (i.e., increases positive emotions like joy and tranquility; Sharam et al., 2023; Ojala et al., 2023; Mattila et al., 2020), in the cognitive domain (i.e., improves working memory, attention, and problem-solving skills; Kaplan & Berman, 2010; Berto, 2005) and also facilitates stress resilience (Gentile et al., 2023; Wang et al., 2019; Anderson et al., 2017). Environmental Psychology is trying to understand what physical features contribute to generating restorative environments and, to date, there is no complete clarity on the issue. Traditionally, natural environments are considered more restorative than built environments, but places with built elements can also have regenerative effects (for recent reviews see Lee et al, 2022; Spano, 2022). Many studies have shown that the level of restorativeness is higher in the presence of certain "natural elements" such as green spaces (Gentile et al., 2023; Pals et al., 2014), water (Tang et al., 2017) and natural light (Nikunen et al, 2014), otherwise, some studies have highlighted that the presence of man-made artifacts does not always reduce the sense of restorativeness. White et al. (2010) have shown that urban environments with watercourses are valued as restorative as exclusively natural contexts.

Scopelliti et al. (2019) measured the perceived restorativeness levels of pictures representing natural environments and built places with high artistic and historical value and found that both types of environments produced a high sense of restoration.

While there is a large body of literature associating the sense of restorativeness with natural elements (e.g., trees, plants, watercourses), there is a lack of studies concerning the structural characteristics of an environment. By the term "structural characteristics of an environment" we mean the set of features that constitute the structural layout of a scene and allow people, when they are giving a glimpse at the scene, to quickly understand what kind of environment they are faced with and how they can act within it. Many studies on perception have shown that, when people are confronted with a scene, they are not able to grasp all the details at the same time, so their attention is immediately drawn to certain structural characteristics of the scene that allow them to have a quick, if also coarse, representation of the environment (Kimchi et al., 2016; Kimchi & Peterson, 2008; Matsukura e Vecera, 2007; Hecht & Vecera, 2006; Treisman & Gelade, 1980). This mechanism of perception allows subjects to quickly understand where they are and how they can act where they are, the analysis of the details (i.e., single specific elements) will take place at a later stage of the environmental visual exploration. Some authors have defined these structural characteristics as Basic Global Properties (BGPs) of the scenes (Redies et al., 2020; Green & Oliva, 2009; Torralba & Oliva, 2003; Oliva & Torralba, 2001;). BGPs derive from a set of basic features of the images (e.g., lines, edges, contours) which, combined by the visual system, render a quick, albeit rough, representation of the type of place the subject is facing. In particular, BGPs allow an initial distinction between natural and built environments. The idea of the existence of BGPs in images can be connected with theories explaining the sense of restoration generated by certain physical environments. Indeed, Attention Restoration Theory (ART; Kaplan, 1995; Kaplan & Kaplan, 1989) posits that restorative environments possess features capable of automatically and effortlessly attracting subjects' visual attention, thereby allowing for a recovery of cognitive energies expended in guiding voluntary direct attention.

Given the above, supposing BGPs are elements capable of attracting visual attention rapidly and automatically and guiding subjects in distinguishing between natural and built environments, it can be hypothesized that BGPs may contribute to generating the perception of restorativeness (PR). In this study, we consider the sense of restorativeness from the Gestalt perspective, as an "emergent quality" of the scene (Bozzi, 1989), which does not exist in itself but derives from how some features of the scene are combined by the visual perceptual system. Therefore, the aim of this study is twofold:

1) Understand whether certain BGPs of a scene (i.e., expansion, depth, openness, transience, concealment, and navigability) play a role in generating PR. Based on the Scene Centered Approach (SCA, Green & Oliva, 2009; Torralba & Oliva, 2003; Oliva & Torralba, 2001), we defined BGPs as a combination of basic features of the image (e.g., lines, edges, contours) that, rapidly attracting visual attention, allow humans, at first glance, to quickly understand the meaning of the scene. According to Attention Restoration Theory (ART; Kaplan, 1995; Kaplan & Kaplan, 1989), we hypothesize these features may constitute the basis of the mechanism generating PR.
2) Identify a way to measure the BGPs from a psychophysical perspective. Since the BGPs are embedded with the image, referring to low-level visual features, like the combination of lines, contours, edges, etc., they are not easy to identify and assess for subjects. To date, in order to measure low-level visual features, computational models have been used (Yu, Xia, Gao e Samal, 2016; Jia, Qi, Li& Lu, 2016). These mathematical models estimate the exact amount of low-level visual features (e.g., straight and curved lines, parallel items) present in images. In this study, however, a psychophysical perspective is adopted - i.e., we are interested not so much in quantifying the exact number of low-level visual features in images, but in understanding whether and how the human visual system grasps BGPs and whether it can capture differences in BGPs levels between different images. For this purpose, we used two different measurement methods - i.e., two distinct groups of subjects were presented with 8 images and were asked to evaluate BGPs and PR with a judgment on a single image at a time, using a 7-point Likert scale, and with a pairwise comparison between images, using a dichotomic scale. In this way, we were able to check the correspondence between the two measurements, to have more confidence about the validity of the metrics.

This paper consists of the following sections: in the first part, the construct of restorativeness referred to physical environments will be analyzed. Then the BGPs of an image, from the perspective of the SCA, will be described. It will be explained how BGPs can be related to the construct of restorativeness. The next section will illustrate the images used for the study, the two measurement methods adopted to assess BGPs and PR, and the analyses conducted on the obtained data. In the last section, the results of the analyses, the strengths and weaknesses of the study will be discussed, along with some practical implications for the field of Environmental Psychology.

1.1. The Construct of Restorativeness in Physical Environments

Restorative environments/images produce positive responses in people's emotional and cognitive domains (Hartig, 2004). Environmental Psychology demonstrated that the exposure to restorative environments, whether real or virtual, enhances positive emotions, such as calm and relaxation (Evensen et al., 2017; Li, Kobayashi, Inagaki et al., 2012; Jahncke, et al., 2011; Tsunetsugu, Park & Miyazaki, 2010; Barton & Pretty, 2010; Kim, Ren & Fielding, 2007; Stigsdotter & Grahn, 2003), improves concentration, working memory, and cognitive functions (Bauman et al., 2023; Ojala et al., 2023; Grahn & Stigsdotter, 2010; Alvarsson et al., 2010; Wang & Taylor, 2006; Biederman & Vessel, 2006; Petherick, 2000; Ulrich, Simons, Losito et al., 1991), and increases the ability to cope with stressful situations (Brown, Barton & Gladwell, 2013; Pheasant, Fisher, Watts et al., 2010; Alvarsson, Wiens, & Nilsson, 2010; Park, Tsunetsugu, Kasetani et al., 2009; van den Berg, Hartig, & Staats, 2007; Biederman & Vessel, 2006; Tsunetsugu & Miyazaki, 2005; Hartig, Evans, Jamner et al., 2003; Ulrich, Simons, Losito et al., 1991).

Various theories are at the basis of these effects. The Biophilia Hypothesis (Wilson, 1984) posits that humans have an innate tendency to experience a sense of restoration in natural environments. Since humans evolved in natural environments with specific characteristics -particularly savanna-like habitats with wide open areas, shrubs for shelter, and watercourses for survival - such environments are thought to elicit positive emotional responses, signaling the presence of resources and the absence of threats. Ulrich's Stress Recovery Theory (SRT, Ulrich, 1983; 1991), based on the Biophilia Hypothesis (Wilson, 1984), states that contact with natural elements (i.e., water, trees, plants) elicits immediate and unconscious positive emotions (e.g., calm and pleasantness) that, in turn, facilitate restoration and stress resilience. Instead, Attention Restoration Theory (ART, Kaplan & Kaplan, 1989; Kaplan, 1995) focuses on humans' cognitive responses in the presence of natural elements. ART postulates that natural environments - specifically because they are habitats in which humans evolved over millions of years - are easy to recognize and understand for the human perceptual visual system. In other words, natural environments have characteristics that attract visual attention automatically and without effort, allowing the recovery of cognitive fatigue deriving from voluntary attention. ART argues that humans, in contact with natural places, are regenerated because these environments are embedded with features attracting and guiding attention, providing cognitive refreshment. The Perceptual Fluency Account (Joye and van den Berg, 2018), as well, leads the sense of restorativeness to the presence in natural environments of features (e.g. redundancy, fractals) that make perceptual image processing “smooth” and effortless. In summary, according to these theories, regenerative environments have features that elicit pre-cognitive (emotional or perceptual) responses that, in turn, produce well-being in subjects.

Based on these theories, various instruments measuring the perceived restorativeness in physical environments have been developed, i.e., the Restorative Component Scale (Herzog et al., 2003), the Restoration Scale (Han, 2003), and the Perceived Restorativeness Scale (PRS, Hartig et al., 1997). These instruments, according to ART, measure the extent to which an environment elicits “soft fascination” which is an automatic attention-grabber, in a non-coercive manner. Since soft fascination is automatic and effortless, it allows the recovery from the prolonged use of voluntary attention that can produce negative emotions, irritability, and stress. In particular, the construct of restorativeness related to physical environments is traditionally composed of four fundamental sub-dimensions:

1*) Fascination*. The capacity of one place to arouse interest and a sense of aesthetic pleasantness. A fascinating environment is composed of a combination of features that capture attention and prompt the subject to contemplation. A fascinating environment is capable of arousing wonder, i.e., a feeling of surprise mixed with admiration that is experienced at the presence of something unexpected, extraordinary, and judged to be very beautiful.

2) *Being Away*. The extent to which a place allows the subject to range with the imagination and feel far away from everyday life. Such an environment possesses unusual features because of the way they are placed or combined. They are capable of activating imaginative processes that allow subjects to momentarily break away from the routine of daily activities. In short, these environments allow subjects to “take a break” from routine and recurring situations.

3) *Coherence*. This dimension pertains to the perceptual and conceptual structuring of the parts that compose the environment. It is the extent to which elements are perceived as an ordered whole. The environmental features are detected as orderly, harmonious, and coherent for the context. The elements are

combined in a way that makes sense, they are also functional for the activities one must perform in the environment.

4) *Scope*. It refers to how the areas surrounding the scene, and also the parts that are not seen but imagined, are considered explorable. Environments with high scope are places with no barriers, that invite to explore, going farther, moved by curiosity to discover what lies beyond the visible part of the scene. These are easily accessible places with no obstacles in the ground and no threatening aspects (e.g., dark or dimly lit spots) that might signal dangers.

Natural places are typically associated with higher levels in restorativeness sub-dimensions, compared to built environments (Gentile et al., 2023; Tang et al., 2017; Nikunen et al, 2014; Pals et al., 2014;). However, some human-built places (e.g., villages with artistic content, squares with high architectural value, and the night skylines of cities) are perceived as restorative as natural environments (Lee et al., 2022; Scopelliti et al., 2019; White et al., 2010). These findings lead one to think that, with regard to natural environments, it is not the mere presence of single natural elements (e.g., water, plants, flowering meadows) that generates restoration but this effect results from more global structural and functional environmental characteristics. According to SCA, environmental structural and functional characteristics are signaled by the presence of some basic global properties (BGPs) of the scene that usefully suggest how the environment is composed and how one can act within it. The BGPs identified by the SCA, serving as facilitators of the distinction between natural and built environments, appear to be more pronounced in natural places, so a high level of BGPs could be related to high perceptions of restorativeness.

1.2. The Basic Global Properties of a Scene: what Lies under Perceived Restorativeness?

In this research, we aim to integrate Attention Restoration Theory (ART) with studies on the functioning of the human perceptual system at the early stage of vision. According to ART, the sense of restoration elicited by a place derives from four characteristics (i.e., fascination, being away, coherence, and scope) that make the environment capable of attracting the subject's attention in a "soft manner", raising curiosity along with a sense of order and harmony. To date, it is unclear which environmental features enable restorative places. We hypothesize that the regenerative characteristics theorized by ART are somehow connected to the perceptual processes activated at an early stage of vision, when subjects encounter a new environment/scene and are engaged in meaning attribution. These initial perceptual processes, which operate in a pre-cognitive phase guiding subjects in decoding the scene in front of them, are due to the visual system's ability to rapidly detect and aggregate certain basic visual features that are present in the image.

Concerning how humans perceive the places they inhabit, literature has shown that subjects recognize new environments very quickly, effortlessly identifying the structure, function, and meaning of the scene (Fei-Fei & Perona, 2005; Potter, 1975). Subjects can also distinguish, at first glance, between scenes representing natural or built environments (Green & Oliva, 2009; Sanocki, 2003; Oliva & Torralba, 2001). These abilities are due to the way the human visual system works. The Scene Centered Approach (SCA, Oliva & Torralba, 2002; Green & Oliva, 2009) states that the visual system, when encountering a stimulating configuration (i.e., a set of physical visual stimuli that must be linked and matched to each other), initially considers it as a whole, immediately focusing on a restricted number of basic elements (i.e. low-level visual features like lines, contours, and edges) rather than on individual, specific objects. This rapid low-level visual feature "attentional capture" enables subjects to have a quick and global representation of the salient characteristics of the scene (i.e., Basic Global Properties, BGPs), to rapidly understand what kind of environment they are in and how to act in it. As proof of this mechanism, Tversky & Hemenway (1983), Torralba & Oliva (2003) Green & Oliva (2009), and Celikors & Wells (2022) have shown that visual configurations that share the same patterns of low-level visual features tend to have the same spatial structure and offer similar possibilities for interaction with the environment (e.g., the image of a forest is composed of an enclosed space with a large number of straight vertical elements where there is limited opportunity to walk freely). SCA is also in line with research on the relationship between automatic/bottom-up visual attention and low-level visual features in an image. The early studies of Treisman and Gelade (1980), concerning how the visual system constructs meaningful images, argued that, at first glance, the visual system can process only a limited number of low-level visual features (e.g., color, orientation in the space, and shape of visual items). These features attract attention immediately and automatically and make it possible to create an initial, albeit coarse, representation of the structure of the environment in which the subject is. Wolfe's visual search experiments (Wolfe, 1994; 2021) demonstrated that, in the process of searching for a target among distractors, the increase in the number of distractors does not impair the performance if the target has one or more salient low-level visual features (e.g., color, brightness, and shape) that attract attention in a bottom-up manner and enable the quick detection of the target. Furthermore, Kimchi's studies (Kimchi & Peterson, 2008; Kimchi et al., 2016) showed that visual attention, when encounters a stimulating configuration, in order to make it sense, immediately relies on certain basic Gestaltic relations between visual stimuli (e.g., similarity, parallelism, and symmetry) and this attentional mechanism aids in the sense construction of the image. This body of literature shows that some basic features in the images exist that, at first glance, attract visual attention in a bottom-up manner and, leading to the "construction" of the percept, facilitate the comprehension of the percept's meaning.

Considering the above, we hypothesized that a link may exist between the BGPs of a scene identified by SCA and the perception of restorativeness, i.e., it is believed that specific patterns of low-level visual features resulting in the BGPs of an image, at first glance, attract attention contributing in the experience of restoration. As demonstrated in the literature, while it is true that some low-level visual features attract automatic visual attention by allowing a rapid understanding of the meaning of a scene, and while BGPs identified by the SCA are compositions of low-level visual features that, being present to a greater extent in natural environments, facilitate the distinction between natural and built scenes, BGPs may play a role in generating the restorativeness sub-dimension (i.e., fascination, being away, coherence, and scope). In this research, six BGPs derived from SCA (Oliva & Torralba, 2001; Green & Oliva, 2009), were considered as possible factors facilitating perceived restorativeness. They are:

1) *Openness*: it indicates how open and spacious a scene is, rather than closed and restricted. In a scene with high levels of openness the gaze can freely range to all sides of the panorama. The scene has a straight and visible horizon line (i.e., the line that ideally separates the earth from the sky), with no foreground features (e.g., stones, trees, or buildings) obstructing the portion of the visible sky.

2) *Expansion*: it provides the perspective of the scene. An image with high expansion is composed of many parallel lines converging at a single point with the function of vanishing point. The presence of a central vanishing point draws the gaze, allowing a glimpse even of elements that are far away from the observer. An example of a scene with high expansion may be the image of a mountain path, bordered by trees, forming two straight and parallel lines converging towards a single central point.

3) *Depth*: it provides the sense of depth of the scene. Images with high depth have elements placed on different perspective planes, with large elements in the foreground and other elements on

different scales. The presence of large features in the foreground and smaller elements in the background gives the impression that there is a lot of distance between the foreground and background, also providing the image a sense of three-dimensionality.

4) *Transience*: it concerns how much the scene, from one glance to the next, can change. Images with high transience are characterized by elements that suggest a high sense of movement (e.g., water, streams, or sky with clouds moved by the wind), providing the idea that something in the scene is "alive" and will change at any moment. Contrary, static elements (e.g., stones or buildings), suggest the possibility of few changes and only over a long time.

5) *Concealment*: it concerns the possibilities that the scene offers for hiding or refuge among the elements of the environment. There are some places in which subjects are completely exposed to the sun or weather (e.g., a desert that is a long stretch of sand, with no other visible elements within it) and others in which natural elements (e.g., trees, caves) offer the possibility of hiding and refuge.

6) *Navigability*: it refers to how freely the subject can move in the environment. In scenes with high navigability (e.g. meadows, fields), the subject can move in all directions, not being hindered by elements in the passage. On the contrary, there are scenes with low navigability where the subject (e.g., due to the presence of water barriers or rocks) has the impression of being stuck in the place.

Between these BGPs devised by SCA, openness, expansion, and depth are defined structural properties of the scene, because they provide important insights regarding the spatial structure of the image (e.g., how enclosed or wide the space is, how far into the distance it is possible to see). Transience, concealment, and navigability, otherwise, are defined functional properties of the scene because they provide important insights about the type of environment one is in (e.g., high-transience aquatic environments vs low-transience rocky places) and what one can or cannot do in it (e.g., take shelter, move and explore freely). Table 1 provides a synthetic description of the BGPs investigated in the study and their main characteristics.

The BGPs described above, according to the SCA, help in the quick distinction between natural and built environments, as these properties are usually present to a greater extent in natural rather than built places. We hypothesize a link exists between these BGPs and the restorativeness sub-dimensions devised by ART. Indeed, for each restorativeness sub-dimension (i.e., fascination, being away, coherence, and scope), we can relate one or more BGPs (i.e., openness, expansion, depth, transience, concealment, and navigability).

- Regarding the ART *fascination*, open scenes, with a broad view (i.e., high openness), tend to be fascinating because they offer a wide field of vision and multiple stimuli that can capture attention instantly and automatically. Depth cues of a scene also contribute to fascination, as they provide a sense of vastness that engages visual and mental interest. Otherwise, transient features in the scene (e.g., changing light, the movements of water) add dynamic, changing elements that maintain curiosity and attention.
- For the *being away* ART dimension, spaces with high levels of openness and depth create the perception of “being far” from routine or familiar environments, allowing for an experience of distance and change. The sense of concealment may also favor being away. Indeed, being in a partially hidden space offers a sense of privacy supporting detachment. Furthermore, navigability (i.e., the ability to explore the scene) increases curiosity, enhancing the idea of being “somewhere else”.
- For the *coherence* ART dimension, depth in a scene helps in structuring information, giving a sense of visual order that facilitates the comprehension of the environment. Even expansion and openness make a scene visually organized, providing clear reference points and suggesting coherence and continuity.
- Finally, depth combined with transient elements, can favor the *scope* ART dimension. Deep and transience add perspective to the scene, enhancing the sense of vastness and environmental complexity. An environment with high levels of openness and expansion provides the perception of breadth, enlarges exploration possibilities, and makes the spatial experience richer. Finally, navigability (i.e., ease of movement) expands the sense of discovery, allowing a dynamic exploration of the environment.

Based on the above, we hypothesize:

H1: In natural scenes, the Basic Global Properties (BGPs) identified by SCA, predict the four dimensions associated with perceived restorativeness (i.e., fascination, being away, coherence, and scope).

Furthermore, as mentioned above, since BGPs can intervene simultaneously in the generation of more than one restorativeness sub-dimension, we propose the following hypothesis:

H2: An interaction effect between BGPs exists in eliciting the sense of restorativeness, such that in scenes where a high level of more than one structural or functional BGP appears simultaneously, the sense of perceived restorativeness is higher, compared to scenes where this does not occur.

1.3. Difficulties in Measuring the Basic Global Properties of a Scene

Since BGPs serve as structural and functional cues in a scene, arising from the human visual system's ability to, first detect, and then integrate some images' basic features (e.g., straight lines, curves lines, edges, contours), measuring the degree of presence of BGPs in a scene may be challenging. Indeed, BGPs are derived from visual elements embedded in the images so an accurate assessment is difficult. For example, the expansion dimension - which is the BGP signaling that, from the observer's point of view, the scene extends beyond what he or she sees and can be explored more in-depth - is given by the presence in the image of a visible and clear vanishing point. According to the rules of linear perspective, the vanishing point results from straight horizontal lines converging at a single point, aligned with the observer's eye level. However, subjects, especially those without drawing skills, often lack a clear understanding of the concept of a vanishing point. Thus, in order to measure the expansion dimension, it is not useful to ask subjects to rate the degree of the presence of a clear vanishing point, according to linear perspective rules. Untrained subjects (i.e., those without specific knowledge of the topic) will be unable to accurately respond to a question like this. Similarly, the depth dimension, the BGP allowing the discrimination between a shallow scene and one with multiple depth levels, indicating the presence of a significant distance between the observer and the furthest visible element in the scene, is conveyed by the level of the texture gradient in the image. A high texture gradient is given by the presence of multiple elements in the image, repeated at different scales. For example, the image of a country path, beginning with larger stones in the foreground and smaller ones in the background, is characterized by a high texture gradient, signaling that the distance between the observer's point and the scene's farthest visible point is substantial. The greater the texture gradient, the more is the depth perceived in the scene. As for the expansion dimension, for an observer inexperienced in design or architecture, evaluating the degree of texture gradient in an image may be challenging. Additionally, since the structural and functional cues expressed by BGPs are usually simultaneously present in a scene, it can be difficult to generate, between different images, accurate, nuanced judgments about the intensity of a particular BGP. For instance, if we ask a subject to rate the level of transience in ten different images and we present, as first image, the picture of a flowing river (which has a high transience level), and the subject rates this picture at the maximum transience level, he or she will be unable to assign a higher rating to the next image, even if it depicts a waterfall with a greater transience level, in comparison to the previous one. This issue similarly applies to the dimensions of concealment and navigability.

In literature, few studies rated the levels of BGPs in an image. To date, in order to make this assessment, computational models evaluating the presence and quantity of the basic features underlying the BGPs in an image (e.g., straight lines, curved lines, parallelism, or collinearity among features) have been used. In a similar research paradigm, researchers ask a computer to estimate the degree of these basic features, to provide an "objective" assessment. For example, if I want to measure the level of openness in an image, I could ask a computer to estimate the extent to which the line composing the horizon line is straight (i.e., unobstructed by other elements) and how many pixels representing the visible sky are present. This is a valid approach when the research's goal is to numerically quantify the basic features in a scene and then to make correlations with certain subject responses (e.g., the number of saccadic movements and eye fixations on specific points in the scene). In this study, we decided to assess BGPs from a psychophysical perspective and, for this reason, computational models are not a useful method. Specifically, we are not interested in determining the objective quantity of basic features constituting BGPs within an image; rather, we aim to understand if and how the human visual system can detect and discriminate among different levels of BGPs. Indeed, in this work, we consider BGPs and the hypothesized associated perception of restorativeness, as a "tertiary quality" of the image. According to authors who inspired Gestalt theories, such as Bozzi (1989) and Michotte (1946), tertiary qualities are those that "emerge" from the image. They do not exist independently but result from how the human visual system aggregates some basic image elements, to generate a meaningful scene. As other authors who have studied environmental restorativeness and its associated features from a phenomenological perspective (Biassoni et al., 2023) have argued, tertiary qualities are pre-cognitive qualities that form at the intersection of physical reality (i.e., the external environment and its physical features) and the subject's perceptual system. As Bozzi stated: *"The shade of a large green tree is relaxing and soothing... Some characteristics inherently attract those adjectives, and these characteristics are not verbal or associative in nature but perceptual ingredients present within the facts themselves. These ingredients emerge from the facts with immediate evidence"* (Bozzi, 1998, p.100). Similarly, we believe that the combination of specific physical basic features in an image, aggregated within the subject's visual system, gives rise to the BGPs of the scene which, in turn, suggest a sense of "restorativeness" related to the observed scene.

Given the above, and considering that, at the moment, in literature doesn't exist a validated measurement scale assessing the BGPs identified by the SCA, we decided to use two different measurement methods to assess the BGPs of an image and the perceived restorativeness (PR) and to compare the obtained results. To achieve this goal, we proceeded as follows. We selected 8 images from a large dataset of 100 pictures previously rated for levels of PR. From this dataset, we extracted the 4 images with the highest PR scores and the 4 with the lowest PR scores, to ensure enough variability among the images in terms of PR levels. Then two different groups of evaluators were involved in the research. The first group of participants was presented with the 8 images, one at a time, and was asked to rate the degree of the 6 BGPs identified by the SCA and the 4 dimensions of PR identified by the ART, using a 7-point Likert scale. A second group of participants was presented with the same 8 images and was asked to evaluate the BGPs and PR dimensions using the pairwise comparison method (Thurstone, 1927). This evaluation method presents the images in pairs, to facilitate the assessment of the investigated dimensions through images' comparisons. Literature has shown that the pairwise comparison method, with respect to single judgments on a Likert scale, provides advantages in measuring dimensions that are difficult to discriminate (Bianchi & Burro, 2023), for the following reasons:

- pairwise comparison is a method simple to understand: subjects are simply asked to compare two images concerning the dimensions under investigation;
- it simplifies the decision-making process: the comparison of two images, unlike the Likert scale that asks subjects to assign an absolute value to each dimension under investigation for one image at a time, allows subjects to have a term of comparison (i.e., the paired image). This simplifies the assignment of judgments even if the images show subtle differences from each other;
- it eliminates response biases: by simply comparing two images, subjects avoid response biases such as central tendency bias (i.e., the tendency to always place oneself in the middle position on a Likert scale) or extreme tendency bias (i.e., the tendency to always place oneself either at the top or at the bottom of a Likert scale);
- it favors detailed judgments: subjects, by making a direct comparison between two images, are facilitated in identifying the differences between the two stimuli. This favors detailed judgments also for dimensions with a certain level of complexity, such as the BGPs of an image investigated in this study.

The pairwise comparison method also has disadvantages. Primarily, since it requires comparisons between all the possible pairs of images, is very time-consuming. Furthermore, if a large number of images is used, it also generates a high cognitive load. In any case, we decided to use two different methods to measure the investigated variables to gain greater certainty regarding the validity of the measurements. Measurements obtained from different methods leading to similar results indicate the measurement is valid. Indeed, if two different measuring instruments lead to similar results, they are likely assessing the same property of the object under investigation.

In the following sections, we will present the study we conducted to verify whether a relationship exists between the BGPs of an image and PR. First, we will illustrate the results obtained with the two measurement methods and then we will show the direct and interaction effects in the relationship between BGPs and PR, obtained through the application of some Mixed Linear Models. Finally, we will discuss the study's limitations, future perspectives, and the practical implications of this research for environmental psychology.

Method

This study consisted of showing subjects eight images depicting natural scenes and asking them to rate the degree of presence of the six BGPs devised by SCA (i.e., openness, expansion, depth, transience, concealment, end navigability) and the four dimensions connected to perceived restorativeness (PR), identified by ART (i.e., fascination, being away, coherence, scope), in order to verify if different levels in scenes' BGPs may predict different levels of PR.

The eight images used in the study were selected from a large dataset of pictures (100 in total), whose PR levels had previously been assessed using the PRS-11 Scale (Pasini et al., 2014). Based on this previous assessment, the four images with the highest levels of PR and the four images with the lowest levels of PR were selected, in order to ensure good variability in the degree of PR between images. For the eight images considered in the study, the levels of BGPs and PR were assessed using two different measurement methods. This assessment was run employing three distinct groups of participants who responded to an online survey In the first step of the research, a group of participants was presented with the images, one at a time and in random order, and the levels of BGPs and PR for each image were assessed, using a 7-point Likert scale (ranging from

1= the investigated property is not present at all, to 7= the investigated property is maximally present). In the second step of the study, the same eight images were presented to different participants (i.e., those who did not perform the previous evaluation), and they were asked to assess the degree of BGPs and PR using the pairwise comparison method (Thurstone, 1946). This method consists of presenting images in pairs and asking participants to indicate which of the two images in pair displays the higher level of the property under investigation, thus producing a dichotomous scale. Literature (Bianchi e Burro, 2023) has shown that this method simplifies the evaluation task, favoring nuanced judgments and reducing biases related to response set and response style. Since no validated scale currently exists to measure the BGPs of an image, two measurement methods were considered useful to compare the obtained results and verify their consistency, aiming to ensure greater measurement validity. For these dual measurement operations, three different groups of participants were involved. A first group (n= 96 subjects) evaluated the BGPs and PR of single images, using the Likert scale; a second group (n= 76 subjects) and a third group (n= 93 subjects) evaluated, respectively, the BGPs and PR levels of images through the dichotomous scale in the pairwise comparison. Three distinct groups of participants were used because those who evaluated images using the Likert scale needed to be different from those using the dichotomous scale. Given that the images remained the same across all assessments, the use of distinct groups of evaluators aimed to prevent participants from becoming overly familiar with the images, as this might lead to decreased accuracy and precision in assessing the variables under study. In addition, regarding the pairwise comparison method, it was necessary to use two distinct groups of evaluators, one assessing BGPs and the other PR. Since the method, though simple in its execution, requires comparing all images with each other, it is time-intensive and the length of the task can lead to cognitive overload, which, in turn, may reduce the accuracy of judgments.

After data collection, the concordance between the two measurement methods was checked using Kendall's Tau index (Kendall, 1938). Then, several Linear Mixed Models (West et al., 2014) were conducted to verify if direct effects exist of BGPs on the single dimensions of PR, as well as to test for interaction effects among BGPs in determining PR.

2.1. Participants

The study involved three different groups of students. The first group (n= 96; 79,17% females; mean age in years= 24.2, SD= 6.32) assessed the levels of BGPs and PR of the eight images by single-image evaluations on a Likert scale. The second group (n= 76; 78.9 females; mean age in years= 22.5; SD= 9.55) assessed the BGPs levels by images' pairwise comparisons on a dichotomous scale, and the third group (n= 93; 76.3 females; mean age in years= 25.2, SD= 8.04) assessed the levels of PR of the images, also using pairwise comparison. The participants in the study were all students from courses of study in Psychology and Social Service Science courses at the University of Verona. Students were recruited through announcements given during their courses, and they participated voluntarily in the research without receiving any monetary reward for their participation.

2.2. Materials

Eight images of natural landscapes were selected from a dataset of 100 images, previously assessed on the perceived restorativeness (PR) levels, using the PRS-11 Scale (Pasini et al., 2014). Based on this previous assessment, a ranking between images was conducted and eight images were extracted - the four with the highest PR levels and the four with the lowest PR levels - to ensure a good variability in the degree of PR between images. All the selected images depict natural landscapes containing different types of natural elements (e.g., forests, meadows, mountains, watercourses, waterfalls) and having no, or only minimally, man-made artifacts (e.g., houses or other constructions). Furthermore, when images were presented to study participants for the assessment, they were always presented in the same format, horizontally oriented (i.e., with the longest horizontal side), and with the same dimensions, in order to avoid judgments being influenced by variations in size and orientation between one image and the next. The images can be found in Appendix A.

The following instruments were used to measure the investigated dimensions:

- for perceived restorativeness (PR), the PRS-11 Scale (Pasini et al., 2014) was used. This scale is a self-report instrument that investigates the four main dimensions connected to the construct of restorativeness, according to Attention Restoration Theory (Kaplan, 1995). The scale consists of 11 items and it represents the Italian-adapted version of the Perceived Restorativeness Scale (Hartig et al., 1997). The dimensions investigated are: 1. Fascination (e.g. item: "In places like this my attention is drawn to many interesting things”), 2. Being Away (e.g. item: “Places like that are a refuge from nuisances”), 3. Coherence (e.g. item: “In places like this it is easy to see how things are organized”), and 4. Scope (e.g. item, “That place is large enough to allow exploration in many directions”). It is based on the idea that the subject’s evaluation of the restorative qualities of an image (i.e., fascination, being away, coherence, and scope) is a valid index of the regenerative psychological experience within the environment depicted by the image. Table 2 shows the PRS-11 Scale.

- For the six BGPs identified by SCA, six ad hoc items were created, one for each investigated dimension (i.e., openness, expansion, depth, transience, concealment, navigability). The item’s definitive formulation resulted from a pilot study involving 13 subjects. In the pilot study subjects performed a task in the laboratory. They were shown the selected images on a full HD 27-inch screen and were asked to respond to the items regarding the BGPs. At the end of the test, each subject responded to a cognitive interview involving the following questions: 1. Was it easy or difficult for you to answer the questions? If it was easy, how did you arrive at the answer? 3. If it was difficult, what made it difficult for you? 4. If it was difficult, how did you arrive at the answer? The cognitive interview enables us to check the item’s clarity and comprehensibility and to verifies whether they measured the dimension of interest. Table 3 shows the ad hoc item to measure BGPs.

The variables of interest (i.e., BGPs and PR) were measured by two methods (i.e., single image presentation with 7-point Likert scale vs pairwise presentation with a dichotomic scale). To make this double measurement possible, items were adjusted between one method and the other. Regarding the pairwise comparison method, it is important to note that:

- for the measurement of PR, PRS-11 Scale items were adapted as follows: the most representative PRS-11 Scale item was chosen for each of the four PR sub-dimensions (i.e., fascination, being away, coherence, and scope) and the selected item was modified in its wording to make it suitable for the pairwise comparison method. For example, for the assessment of the fascination dimension, the item chosen from the PRS-11 is “In places like this my attention is drawn to many interesting things” and it was changed to “Which of these two images draws your attention more?” for the pairwise comparison method. The global perceived restorativeness of each image, which in the original version of the PRS-11 Scale results from the average of the 11 items, was assessed using the following ad hoc item: “Which of the two scenes would you like to be in to recover your energy?”. Table 4 shows the adapted item from the PRS-11 Scale.

- For the measurement of the six BGPs, the items’ wording was slightly modified and adapted to the pairwise comparison method. For example, for the assessment of the openness dimension, the item asking to rate on a 7-point Likert scale “How wide is the scene you see?” was changed to “Which of the two pictures you see presents a wider scene?”. Table 5 shows the adapted items for the pairwise comparison method.

Once the items were defined for the two measurement methods, an online survey was created. The survey was managed through the LimeSurvey platform (Limesurvey GmbH 2023). This tool is an open-source online application, accessible through any web browser, that allows surveys to be conducted. Through LimeSurvey the survey was first created, then published and data was collected.

2.3. Procedure

The survey was conducted online. Participants, all students, were recruited during a psychology class in the Psychology and Social Service Science courses at Verona University. Each participant, individually, accessed the LimeSurvey platform using a personal device (PC or tablet). Participants were given brief indications regarding the research purposes and were asked to consent to participate in the research. If they gave consent, they accessed the survey. Once they entered the survey, to measure the variables of interest, students were divided into three different groups and each group responded to a different section of the survey.

About subjects in Group 1, they accessed the first section of the survey, where the six BGPs were asked to be evaluated on a 7-point Likert scale. The eight natural images were presented, one at a time, with the following prompt: “We ask you to look at the following pictures and answer the questions. To choose your answer, select with a dot only one of the numbers on the scale next to each statement. The scale ranges from a minimum score of 1 (= not at all), to a maximum score of 7 (= very much)”. Once the answers for one image had been completed, the subject pressed the “next” button and moved on to the next image. The presentation of the eight images was randomized for each subject. Once the six BGPs had been assessed, subjects in Group 1 entered the second section of the study, concerning the evaluation of the PR sub-dimensions. The eight pictures were presented again, one at a time, and the subject was asked to answer the items of the PRS-11 on a 7-point Likert Scale, with the following prompt: “We now ask you to look at the following pictures and answer the questions. To choose your answer, select with a dot only one of the numbers on the scale next to each statement. The scale ranges from a minimum score of 1 (= not at all), to a maximum score of 7 (= very much)”. The order in which the images were presented was randomized. At the end of the section, some socio-demographic information regarding gender and age was requested. In total, the subjects answered 136 items, 48 items (8 pictures x 6 items) in the first section of the study and 88 items (8 pictures x 11 items) in the second section. Subjects had no time limit in completing the survey and were advised, in the initial instructions, to take a break if they felt fatigued. The average time to complete the survey was 25 minutes. After the subjects had completed the survey, they were asked if they found the task easy or difficult and if they had any difficulties in answering the questions. In addition, subjects were given a space to ask questions or clarifications related to the research.

About subjects in Group 2, they evaluated the six BGPs for each of the eight selected images, using the pairwise comparison method. For this purpose, an initial screen appeared in which two of the eight images were shown. Subjects had to look at the two images and were asked: “Compare the two images (A and B) and choose one concerning the proposed questions”. After the first comparison, subjects pressed the “forward” button and moved on to the second comparison in which two other images were shown, and so on until they had finished all the comparisons. The order of presentation of the paired images were. At the end of the section, some socio-demographic information regarding the gender and age of participants was requested.

About the subjects in Group 3, who had to evaluate the four PR sub-dimensions of the images, they were presented with an initial screen on which a first pair of images was presented and asked: “Compare the two images (A and B) and choose one concerning the proposed questions”. When the subjects had finished the first comparison, they pressed the “forward” button to access the next comparison, and so on until the end of the comparisons. The order of presentation of the paired images was randomized. At the end of the section, some socio-demographic information regarding gender and age was requested. Subjects in Group 2 and Group 3 had no time limit in completing the survey and were advised, in the initial instructions, to take a break if they felt fatigued. Anyway, the completion of the survey for both Group 2 and Group 3 took approximately 20 minutes in total. Subjects in Group 2 performed a total of 252 comparisons (i.e., 42 image comparisons x 6 items per comparison), and subjects in Group 3 performed 210 comparisons (i.e., 42 image comparisons x 5 items per comparison). After the subjects had completed the survey, they were asked if they found the task easy or difficult and if they had any difficulties in answering the questions. In addition, subjects were given a space to ask questions or clarifications regarding the research.

Data Analyses and Results

3.1. Score Comparison Between Measurement Methods

In this study, the variables under investigation (i.e., PR dimensions and BGPs) were measured using two different methods. The first method - i.e., evaluation of single images by a Likert Scale - involves assigning each image, for each variable of interest, a score, ranging from 1 (= the property is absent) to 7 (= the property is maximally present). Tables 6 and 7 show, respectively, the average scores that each image obtained on the restorativeness dimensions and on each BGPs. This method allows a ranking of images for each investigated property, from the one with the lowest score to the one with the highest score.

The second method - i.e., paired image comparison on a dichotomous scale - involves comparing images two at a time, indicating which of the two possesses a greater degree of the investigated dimension. By placing the scores in a frequency matrix, that crosses images in rows and columns, we can determine how many times, for a given property, one image was chosen over another. This frequency matrix is then converted into a proportion matrix, by dividing each cell's value by the number of evaluators. Finally, the values obtained are transformed into z-scores, which express the proportion as a linear distance. Tables 8 and 9 show, respectively, the z-scores for the restorativeness and BGPs dimensions of the 8 images evaluated by the pairwise comparison method Again, this method provides a ranking of images, from lowest to highest score, across the different examined properties.

The purpose of using two different measurement methods is to determine whether there is correspondence in the scores obtained with the two methods. For this, Kendall's Tau statistic was used. Kendall’s Tau is a non-parametric statistic that measures the correlation between two ordinally scaled variables. It assesses the strength and direction of the relationship between two variables by examining concordance and discordance in pairs of observations. We used Kendall's Tau because it does not require a normal distribution of data. This is particularly relevant for BGPs, which, as perceptual characteristics of images influenced by how certain basic physical items are combined by our visual system, show a certain degree of variability among subjects but not enough to ensure a bell-shaped data distribution. Kendall's Tau compares all possible pairs of observations across two variables to determine concordance or discordance. By subtracting the discordant pairs from the concordant pairs and accounting for the number of estimated pairs, a Tau score is obtained. A positive value indicates a direct correlation between variables, while a negative value indicates an inverse correlation. A Tau coefficient $> .70$ indicates a good level of correlation; a Tau between .31 and .69 indicates a medium level; and a Tau $< .30$ indicates a weak level of correlation.

For the PR dimensions, Kendall's Tau was used to pair each PR sub-dimension score (i.e., fascination, being away, coherence, scope, and overall PR) obtained with the first method with the score obtained with the second method, yielding strong values of Tau index for all dimensions (fascination, T= .71; being away, T= .86; coherence, T= .71; scope, T= .93; overall PR, T= .86). For the BGPs, the same procedure was followed, yielding scores between sufficient and strong for openness (T = .79), expansion (T = .64), transience (T = .71), and concealment (T = .71). In contrast, depth (T = .36) and concealment (T = .07) did not achieve sufficient levels of concordance between the two measurement methods. Tables 10 and 11 show, respectively, Kendall's Tau scores obtained from comparing restorativeness and BGPs measures with the two measurement methods. The results obtained through Kendall's Tau suggest that for the PR dimensions, the two measurement methods produced consistent and reliable results, supporting the validity and reliability of these measurements. For the BGPs, the same conclusion applies to openness, expansion, transience, and navigability, but not to depth and concealment, as results for these dimensions did not appear consistent across the two measurements. It should be noted that PR measurements were conducted using the PRS-11 (Pasini et al., 2014), which is a validated scale, and measurement consistency was expected, while ad hoc items were created for BGPs, as no validated scale exists for these dimensions. Due to insufficient assurance of measurement validity and reliability of the BGBs of depth and concealment, these dimensions were excluded from subsequent analyses in this study. Therefore, the BGPs considered in the following analyses are limited to four BGP dimensions, two representing structural characteristics of the scene/image (i.e., openness and expansion) and two depicting functional attributes of the scene/image (i.e., transience and navigability).

3.2. Direct Effects of Structural and Functional BGPs on PR Dimensions

After verifying, through Kendall's Tau index, the measurement reliability for the dimensions under investigation, the scores of PR and BGPs obtained by the Likert scale measurement were used for the analyses described in this section. First, a correlation analysis, using Pearson's statistic index, was conducted to test for relationships between the four PR dimensions (i.e., fascination, being away, coherence, and scope) and the four BGPs retained after the reliability analysis (i.e., openness, expansion, transience, and navigability). As shown in the correlation matrix in Table 12, navigability correlates positively with all four PR dimensions - fascination ($r = .39$, $p < .001$), being away ($r = .32$, $p < .01$), coherence ($r = .37$, $p < .001$), and scope ($r = .65$, $p < .001$). Transience correlates positively with both fascination ($r = .26$, $p < .05$) and scope ($r = .33$, $p < .01$). Openness correlates positively with both coherence ($r = .28$, $p < .01$) and scope ($r = .41$, $p < .001$), and expansion correlates positively with scope ($r = .33$, $p < .001$). The correlation analysis showed that a direct relationship exists between BGPs and PR dimensions, that is, as BGPs values increase, PR values also increase, and vice versa. Anyway, correlation analysis, while demonstrating the existence of a relationship between the variables under investigation, does not indicate the causality of the relationship.

After the correlation analysis, to test H1 (i.e., BGPs affect PR dimensions), some Mixed Linear Models were employed. Mixed Linear Models (Raudenbush et al., 2002) are statistical models that test linear regressions accounting for both fixed effects (i.e., parameters associated with independent variables, assumed to be the same for all individuals in the sample) and random effects (i.e., variations occurring among individuals in the sample, treated as random variables). These models allow us to test whether BGPs have an effect on PR dimensions, considering the existent variability between images and between subjects.

Regarding the effects of the structural BGPs (i.e., openness and expansion) on PR dimensions, the deviance analysis obtained with a Type II Wald chi-square test shows the existence of a direct effect of openness on fascination (Chi= 18.367, DF= 1, $p < .001$), being away (Chi= 11.055, DF= 1, $p < .001$), coherence (Chi= 10.717, DF= 1, $p < .001$), and scope (Chi= 30.527, DF= 1, $p < .001$). There is also a direct effect of expansion on fascination (Chi= 7.07, DF= 1, $p < .007$), being away (Chi= 3.887, DF= 1, $p < .048$), and scope (Chi= 5.284, DF= 1, $p < .021$). However, no significant effect of expansion on coherence was found (p= n.s.).

For the effects of the functional BGPs (transience and navigability) on PR dimensions, the deviance analysis obtained with a Type II Wald chi-square test shows a direct effect of transience on fascination (Chi= 23.786, DF= 1, $p < .001$), being away (Chi= 9.61, DF= 1, $p < .001$), coherence (Chi= 4.525, DF= 1, $p < .033$), and scope (Chi= 10.582, DF= 1, $p < .001$). There is also an effect of navigability on fascination (Chi= 29.881, DF= 1, $p < .001$), being away (Chi= 37.221, DF= 1, $p < .001$), coherence (Chi= 21.494, DF= 1, $p < .001$), and scope (Chi= 104.481, DF= 1, $p < .001$).

These results confirm H1, indicating that both structural and functional BGPs of a scene/image have a significant influence on the four PR dimensions. That is, changes in the values of scenes/images BGPs (openness, expansion, transience, navigability) are associated with significant variations in the perceptions of the four dimensions of restorativeness (i.e., fascination, being away, coherence, scope). The only non-significant relationship that was found pertains to the effect of expansion on coherence. Figures 1, 2, 3, and 4 show the effects of the structural and functional BGPs of a scene/image on the four PR dimensions (i.e., fascination, being away, coherence, and scope), considered separated.

3.3. Interaction Effects of Structural and Functional BGPs on PR Dimensions

After confirming the existence of direct effects of the structural and functional BGPs of a scene/image on PR dimensions, we proceeded to test Hypothesis 2 (H2). H2 assumes BGPs of a scene/image may interact in influencing PR. Indeed if, as SCA (Oliva e Torralba, 2001; 2002) states, the combination of structural BGPs facilitates the understanding of the environment in which a subject is located (i.e., whether it is natural or not), in a scene/image, a simultaneous increase in structural BGPs scores may enhance the perception of restorativeness more than an increase in only one structural BGP score individually. A similar rationale is applied to functional BGPs.

To test the interaction effects between the two structural BGPs (i.e., openness and expansion) in influencing the four PR dimensions (i.e., fascination, being away, coherence, and scope), Mixed Linear Models were used. The analysis of deviance with a Type II Wald chi-square test did not show statistically significant interactions for the dependent variables fascination, being away, and coherence (p= n.s.). However, for the dependent variable scope, the same analysis demonstrated a statistically significant interaction between openness and expansion (Chi= 5.40, Df= 1; p= .02). These results suggest that, although openness and expansion individually influence fascination, being away, and coherence, there is no significant combined effect between the two variables. For the PR dimension of scope, however, a simultaneous increase in openness and expansion results in a stronger perception of scope, in comparison to an increase in only openness or expansion.

Mixed Linear Models have also been used to verify the interaction effect between the two functional BGPs (i.e., transience and navigability) in influencing the four PR dimensions (i.e., fascination, being away, coherence, and scope). The analysis of deviance with a Type II Wald chi-square test showed interaction effects for all four PR dimensions (fascination, Chi= 3.655, Df= 1; p= .055; being away, Chi= 7.541, DF= 1, p= .006; coherence, Chi= 13.459, DF= 1, p< .001; scope, Chi= 11.242, DF= 1, p< .001). These results indicate that, in a scene/image, the simultaneous increase in openness and expansion enhances the perception of all four PR dimensions more effectively than an increase in only openness or expansion. Figure 5 shows the interaction effect of openness and expansion in eliciting the PR dimension of scope. Figures 6, 7, 8, and 9 show the interaction effect between transience and navigability in eliciting, respectively, fascination, being away, coherence, and scope.

Final Discussion

This research proposes to shed light on the relationship between certain basic global properties of scenes/images (BGPs) and the sense of restorativeness that scenes/images elicit. One of the main topics of Environmental Psychology concerns mechanisms through which environments/images elicit the perception of restorativeness (PR). The literature has shown that environments/images containing predominantly natural elements (e.g., plants, forests, watercourses) favor PR. Still, environments/images containing man-made works (e.g., historical sites) can also generate a sense of restoration. These findings have led some authors to hypothesize that it is not merely the presence of natural elements (e.g., trees vs buildings) that elicits PR, but rather that natural environments/images are characterized by a combination of basic structural and functional features that, taken together, contribute to producing PR. One of the more widely accepted theories regarding the restorativeness construct is the Attention Restoration Theory (ART, Kaplan, 1995), according to which restorative scenes/images possess characteristics (i.e., fascination, being away, coherence, and scope) that attract visual attention in a bottom-up manner, generating “soft fascination” (i.e., the attentional capture in an automatic but non-coercive manner) and, consequentially, PR. Furthermore, the Scene Centered Approach (SCA, Torralba & Oliva, 2001; Green & Oliva, 2009) states that when the human visual system encounters an environment/image, at first glance, visual attention is drawn to image’s “cues” (i.e., BGPs: openness, expansion, depth, transience, concealment, and navigability) that facilitate a rapid understanding of the environment, its characteristics and what activities may or may not be carried out in it. The SCA is in line with a large body of research in psychophysics that has shown that, when the human visual system encounters a stimulating configuration, it is initially attracted to a series of basic features (Treisman & Gelade, 1980; Wolfe, 1994, 2021) and basic “gestaltic relationships” between these features (Kimki, 2016) that facilitate the “construction” of the percept. Based on the evidence mentioned above, in this research, we hypothesized that BGPs identified by SCA (i.e., openness, expansion, depth, transience, concealment, and navigability) may contribute to generating PR, via the immediate attraction of visual attention and through facilitation in recognizing natural environments that carry resources for humans.

Few studies have investigated the relationship between the basic features of a scene/image and PR. This is perhaps because the presence and the amount of these features are not easy to assess. The BGPs devised by SCA refer to the combination of elementary items of the image that contribute to producing a meaningful and coherent perception (e.g., the presence or absence of a visible vanishing point or the presence or absence of multiple planes of depth). Because these features are embedded with the stimulating configuration, they are not easy to detect and evaluate. In fact, to date, there is no validated scale to estimate the presence and quantity of these features. For these reasons, in this research, we used two different measurement methods (i.e., evaluation of single images on a 7-point Likert scale vs. pairwise comparison of images on a dichotomous scale), in order to ensure the measurement validity and reliability of the construct we are examining. The pairwise comparison, by directly comparing only two images at a time, is believed to facilitate the estimation of the dimension under investigation (i.e. BGPs), reducing subjects’ cognitive effort and preventing response biases. Any concordance between the two measurement methods is believed to be a greater assurance of the validity and reliability of the measure. Kendall's Tau's statistical index, which was used to test the correspondence between the two measurement methods, showed concordance between the two measures for the structural BGPs openness and expansion and for the functional BGPs transience and navigability. However, for the BGP depth (i.e, the presence of multiple perspective planes in the scene as an indication of depth) and concealment (i.e., the presence of "clues" suggesting the possibility of hiding/repair in the environment) not enough concordance was found to consider the measurement valid and reliable. For this reason, depth and concealment were excluded from the subsequent data analyses, run on Likert scale scores, aimed at verifying H1 and H2 by the use of Mixed Linear Models.

4.1. The Relationship between the Basic Global Properties of the Scene/Image and the PR Dimensions

To test the relationship between the Basic Global Properties (BGPs) of an environment/image identified by the Scene Centered Approach (SCA) and the perception of restorativeness (PR), the scores for the BGPs (i.e., openness, expansion, transience, and navigability) and PR dimensions (i.e., fascination, being away, coherence, and scope) of eight images, obtained by the measurement on Likert scale, were used. These scores were analyzed using Mixed Linear Models (LMM). LMM allows for linear regressions that account for random effects among images and subjects. These models tested both the direct effects of BGPs on PR and the interaction effects between BGPs in eliciting PR.

The results showed that each BGP, taken individually, can influence the PR dimensions; that is, the increase of a single BGP corresponds to an increase in the dimensions of PR. This was consistent across all direct effects that were tested, except for the effect of expansion on coherence (i.e., variations in expansion scores do not affect the PR coherence dimension). These findings support H1, which posits that BGPs of a scene/image - derived from the aggregation of basic items present in the scene - represent the initial elements upon which visual attention focuses, aiding in the rapid comprehension of an environment's structural and functional characteristics. As established by SCA (Oliva & Torralba, 2001; 2002), BGPs enable quick differentiation between natural and built environments. Given that BGPs are more abundant in natural settings, they can be considered predictors of PR. For example, an image with a high score on openness (i.e., an expansive view allowing the gaze to move freely in all directions) - compared to an image with a more restricted view - can foster a sense of fascination (i.e., aesthetic pleasure combined with surprise/wonder) and being away (i.e., the feeling of escaping from the daily routine). Similarly, a substantial level of expansion in an image (e.g., the presence of a central vanishing point providing image depth and directing the gaze toward an image's point in the distance) can enhance fascination and being away. Structural BGPs of scenes/images, like openness and expansion, can also contribute to a sense of environmental coherence (i.e., order, harmony) and encourage the viewer to explore the surrounding environment (i.e., scope). Furthermore, a high transience score (i.e., the functional BGPs indicating the presence of elements in motion in the image, such as clouds or water flows), compared to a static image, can promote fascination and being away, once again inviting exploration (i.e., scope). An image with high navigability (i.e., lack of barriers/obstacles that hinder free movement) can enhance not only fascination and being away but also coherence and scope.

Regarding H2 (i.e., the existence of an interaction between BGPs in eliciting PR), results confirmed that functional BGPs, such as transience and navigability, interact with each other in eliciting the four PR dimensions. Furthermore, for structural BGPs, also openness and expansion interact, but only in eliciting scope. This implies that, in an image/scene, the simultaneous enhancement of multiple BGPs increases perceived restorativeness more than the increase of a single BGP at a time. This result is also consistent with SCA. Since all BGPs represent "cues" indicating that the subject is within a natural environment, it is expected that they collectively contribute to eliciting PR. However, the results showed that the interaction effect is more pronounced for functional BGPs - those indicating the actions that can be taken in the environment - compared to structural BGPs, which signal the environmental spatial layout.

4.2. Final Observations and Future Perspectives

This study provides an initial insight into the relationship between the perception of restorativeness and certain environmental basic global properties (BGPs) of a scene/image. It was hypothesized that BGPs, by providing a rapid and overall understanding of the type of environment in which the individual is situated and helping identify natural landforms that - from an evolutionary perspective - are resource-bearing, could influence the perception of restorativeness.

Although this is an exploratory study, it demonstrates that both, the structural BGP openness (i.e., the breadth of view in an image) and expansion (i.e., the presence of a central vanishing point providing a sense of depth in the image), and the functional BGP transience (i.e., the presence of movement cues) and navigability (i.e., the absence of obstacles to free movement in the environment), influence the four dimensions associated with the sense of restorativeness: fascination, being away, coherence, and scope. Furthermore, the study shows that an interaction between BGPs enhances the feeling of PR. In particular, an interaction effect was found between the functional BGPs transience and navigability in eliciting PR.

Despite these encouraging results, it should be noted that the BGPs identified by SCA are originally six but the BGP depth and concealment were excluded from the analyses for direct and interaction effects because the two measurement methods used in the study (i.e., single-image ratings on a 7-point Likert scale and paired image comparisons on a dichotomous scale) did not agree. Indeed, since there is no validated scale in the literature to measure BGPs, an ad hoc item was created for each BGP, and two measurement methods were compared, as an agreement between the two measures provides greater assurance of validity and reliability of the measurement instrument. For the BGP depth (i.e., the presence of “clues” providing the image a sense of depth and tridimensionality), a possible explanation for the discordance between the two measurement methods may lie in the poor formulation of the item that captured this dimension. Indeed, participants were asked to rate "how much they could see into the distance in the image." It is possible that this formulation was too vague and confusing for participants, as multiple “cues” in the image might be taken as reference points to evaluate the distance between their point of view and the farthest visible point in the scene. In the presence of images with similar depth levels, it may be complex for participants to make such a nuanced evaluation, especially when assessing images individually, without other images as a point for comparison. As for the BGP concealment (i.e., the presence of elements suggesting the possibility of shelter or concealment), the lack of agreement between the two measurement methods may be due to an incorrectly formulated item. Indeed, in the single-image rating method on Likert scale, participants were asked to assess to what extent they thought they could find shelter or concealment in the depicted environment, while in the paired image comparison method, participants were asked to evaluate which of the two images they felt more exposed (e.g., to the sun, weather elements). This formulation was chosen because it was thought - probably erroneously - that one item would represent the reverse formulation of the other. However, it appears this is not the case - i.e., asking how exposed one feels and assessing the perceived ability to find shelter among environmental elements is not the same - since Kendall's Tau showed, as expected, a negative relationship between the two measures, but the strength of the relationship was very weak, indicating that the two items do not measure the same construct. Therefore, the formulation of items related to depth and concealment will be revised, and a further study with different images will be conducted to assess these dimensions and to correlate these BGPs with PR.

Another noteworthy point is that the SCA provides an overall but not detailed description of the visual elements that contribute to the perception of each BGP within images. A further step of the research may be a more specific identification of the visual stimuli, or aggregations of stimuli, that constitute each BGP. Various theories that have addressed visual perception - from Gestalt theories (Kaniza, 1980) to more recent studies on visual attention (Kimki & Peterson, 2008; Kimki et al., 2016; Wolf, 1994; 2021) - indicate that, in a visual configuration, at first glance, the visual attention is rapidly drawn to certain basic features, or feature relationships, that facilitate the grouping of perceptual elements and aid the construction of a meaningful image. For SCA, BGPs of an environment/image are those dimensions that ease, at first glance, the understanding of the image's structure and function. BGPs can therefore be associated with certain percept's basic features that Gestalt studies have already identified as fundamental for image construction. For instance, the greater or lesser proximity of visual items (i.e., Gestalt proximity) may result in greater or lesser openness (i.e., the extent to which the scene appears spacious and open). The similarity in size of visual items (i.e., Gestalt similarity), setting up the image's texture gradient, may affect depth (i.e., the sense of depth and three-dimensionality of the scene). The Gestalt continuity of directional segments may influence expansion (i.e., the presence in the image of a central vanishing point allowing one to see into the distance). The Gestalt directionality of structure (i.e., visual items tending to align along the vertical or horizontal axis of the image) may affect levels of navigability (i.e., the sense of being able to move freely within the environment). The Gestalt principle of closure (i.e., segments converging to form closed shapes) may play a role in concealment (i.e., the presence of "cues" suggesting that one could find shelter or concealment in the environment).

In line with the above, further studies could be conducted to deepen our understanding of the relationship between BGPs, Gestalt elements of the image, and the perception of restorativeness. Indeed, it could be that specific combinations of basic Gestalt elements in the scene, favoring the understanding of BGPs, positively influence perceived restorativeness. If BGPs serve as "clues" that support a quick and holistic perception, facilitating the detection of natural environments, the visual elements identified by Gestalt theories may act as the "fundamental building blocks" that enhance the perception of BGPs and the associated sense of PR.

4.3. Limitations of the Research

Further studies about the relationship between BGPs of scenes/images identified by SCA and PR may be conducted to overcome certain limitations of this research, which may have influenced the results. Firstly, a small number of images (i.e., 8 pictures) were used in this research because, to implement the pairwise comparison method, a limited number of stimuli is recommended. About the use of this methodology, due to the large number of comparisons that need to be made - more images would require a long time to evaluate the investigated features and this could increase the cognitive load and, consequentially, response biases. In the future, using different groups of respondents evaluating different subgroups of images, would give the possibility to consider a numerically larger sample of images. Furthermore, the selected images all depicted natural landscapes - because in this research, based on previous studies, it has been hypothesized that BGPs are more prominent in natural environments - but BGPs are present also in built environments, although probably to a lesser degree. If a larger sample of images could be used, the different levels of BGPs and PR could be compared by differentiating between images depicting natural and built environments.

A second aspect that needs to be considered is that the images used in this research were selected from a dataset of 100 natural images, previously assessed on the level of PR. From this dataset, the four most restorative and the four least restorative images were taken, in order to create variability in PR levels of the images sample. This procedure may have resulted in little variability in the natural characteristics of the depicted scenes - e.g., there are no gardens, parks, or dense forests. In addition, many images represent fairly large landscapes, in fact only id 35 is the close-up of a flower meadow. A low variability could also result in the structure of the represented scenes. Only id 41 has a very different structure from the other images (i.e., it depicts a waterfall enclosed between rocks, with a lot of "clues" for concealment). Little variability in the characteristics of the images may have conducted to a "ceiling effect" or a "floor effect" - i.e., the images, being all similar, could all have high or low scores in the assessed BGPs - and this may have led to a bias in the analyses, especially in testing the interaction effects between BGPs in eliciting PR. In order to fill this gap, future research is needed in which the images to be evaluated on the level of PR are chosen for the fact that they have great variability in the levels of BGPs associated with the scene. Furthermore, as mentioned above, the images used in the research were selected on the basis of the PR scores. In subsequent studies, attention should also be paid to ensure that images are balanced for other aspects that may affect PR but do not concern BGPs of the scene, like the brightness level and colors. Indeed, id 19, which is the image with the highest PR scores, has significantly higher levels of brightness and color variability, with respect to the others. Another factor that the literature has shown to influence PR is the presence of watercourses - i.e., water is an element that increases the sense of restorativeness. In this study, an a priori balancing between figures painting watercourses and figures lacking this element was not conducted. Considering the above, an enhancement in the variability of the natural characteristics of the depicted scenes and, simultaneously, better control for other characteristics that may affect PR (e.g., colors, brightness, the presence or absence of water), may help to obtain clearer results regarding the relationship between BGPs identified by SCA and PR.

4.4. Practical Implications of the Results

In conclusion, we would like to draw some implications of this research. By shedding light on the link between BGPs of an image/environment and the associated perception of restorativeness (PR), this study has relevance in the context of the theories about restorativeness, developed in the field of Environmental Psychology. In particular, ART (Kaplan, 1995) asserts that PR is generated when the image/environment has characteristics capable of attracting visual attention automatically. It is precisely the "involuntary attention capture" that favors the recovery of cognitive energy spent on tasks in which voluntary attention is required. According to ART, this "attentional capture" mechanism generates a sense of restoration. The results of this research support the ART hypothesis. Indeed, it has been shown that certain basic global structural and functional characteristics of the scene (i.e. BGPs, openness, expansion, transience, and navigability) exist that are associated with the four dimensions of restorativeness identified by ART (i.e., fascination, being away, coherence, and scope). These basic environmental characteristics, according to the SCA, are those which, at first glance, automatically attract visual attention, facilitating the percept construction and, in particular, favoring the ability to distinguish if the environment in front of us is a natural or a built one. It should also be noted that BGPs of the scene associated with PR result, at least partially, from the combination of basic visual items that Gestalt theories have shown to be related to visual automatic attention (e.g., parallelism of lines, similarity in the size of items; Treisman & Gelade, 1980; Kimchi, Yeshurun, Spehar & Pirkner; 2016; Kimchi & Peterson, 2008). However, on the relationship between BGPs and gestalt properties of images, further studies need to be conducted.

In conclusion, this research supports the hypothesis that if a scene/environment is rich in basic "clues" that facilitate perceptual construction and also facilitate the identification of natural environments - which, from an evolutionary point of view, represent resources for humans - it, compared with a scene/environment lacking in these respects, elicits a greater sense of perceived restorativeness. This research demonstrated that BGPs of the scene identified by SCA are elements that contribute to generating this restorative effect. Of course, there are also other basic features of a stimulating configuration that have been shown to attract automatic attention (e.g., brightness and color contrast of the image; Wolfe, 1994, 2021), but those elements were not the focus of this study.

These results are not only of theoretical relevance, they may also have practical implications. If we understand which basic features of a visual configuration favor a sense of restorativeness, we can try to favor the presence of these elements while designing urban environments or workplaces, in order to increase the sense of restoration that people experience when inhabiting these places. To date, Environmental Psychology does not have a defined list of the environmental elements that favor restorativeness perception, and studies on the basic structural and functional elements producing these effects can be useful to give substance to the theories on restorativeness, implementing a list of features that help design public spaces and interior environments. Each of the BGPs considered in this study (i.e., openness, expansion, transience, and navigability) can serve as a framework for creating spaces that promote restorativeness and psychological well-being. For instance, to enhance openness, interior spaces can be conceived as open-plan layouts, where furniture is arranged to avoid visual flow obstruction. Additionally, large windows, skylights, or reflective surfaces can be incorporated to amplify the sense of openness within the environment. To foster expansion in built spaces, visual amplifiers such as mirrors can be employed to create the illusion of greater spatial depth, while architectural lines - horizontal or vertical - can guide the observer's gaze. Incorporating elements that direct attention outward, such as balconies or terraces, can further contribute to this effect. In terms of transience, dynamic elements, like adjustable lighting or modular furniture, can be used to introduce a sense of change or movement. Similarly, incorporating plants or fountains that evolve over time can imbue interiors with a feeling of variability. Finally, to promote navigability, may be important to arrange furnishings logically, ensuring clear and accessible pathways, while adhering to ergonomic principles that minimize obstacles or awkward angles. Including visual cues, such as signage or focal points, can also facilitate spatial orientation and improve navigability. These examples underscore how BGPs can guide the design of restorative spaces that support mental health and well-being.

Appendix

Table 1

Description of the six basic global properties of a scene considered in the study

Global property	Description	Provided information about the scene
Openness	It indicates how wide the scene is, i.e., there is the possibility to range the gaze to all sides of the image or, on the contrary, how closed the scene is, i.e., there are natural (e.g., stones) or built elements (e.g., objects) that limit the view	Spatial structure of the scene
Expansion	It provides the sense of perspective of the scene. It ranges from very flat scenes, with a single horizontal line delimiting the horizon, to scenes with many parallel lines converging at a single point, with the function of vanishing point	Spatial structure of the scene
Depth	It provides the sense of depth of the scene. It ranges from shallow scenes, in which the elements are depicted on a single plane (e.g., in the foreground), to scenes in which the elements are depicted in various scales of size, providing a sense of high depth	Spatial structure of the scene
Transience	It concerns how much the image, from one glance to the next, can change. It ranges from scenes with a broad sense of movement (e.g., if streams or falling leaves are present) to static images, which can change only over geological eras (e.g., stones)	Temporal constancy of the scene
Concealment	It concerns the possibilities that the scene offers for hiding among the elements of the environment. It goes from scenes in which the subject is completely exposed (e.g., a desert) to scenes in which natural elements offer the possibility of hiding and refuge (e.g., trees, rocks)	Function of the scene (possibility of interaction between the subject and the environment)
Navigability	It refers to how freely the subject can move in the environment. It varies from scenes in which movement is greatly restricted (e.g., for the presence of boulders) to scenes in which the subject can move in any direction (e.g., a field of flowers)	Function of the scene (possibility of interaction between the subject and the environment)

Table 2

PRS-11 Scale and the Dimensions Underlying the Scale

Nr	Item	Dimension
1	Places like that are fascinating	Fascination
2	In places like this my attention is drawn to many interesting things	Fascination
3	In places like this it is hard to be bored	Fascination
4	Places like that are a refuge from nuisances	Being away
5	To get away from things that usually demand my attention I like to go to places like this	Being away
6	To stop thinking about the things that I must get done I like to go to places like this	Being away
7	There is a clear order in the physical arrangement of places like this	Coherence
8	In places like this it is easy to see how things are organised	Coherence
9	In places like this everything seems to have its proper place	Coherence
10	That place is large enough to allow exploration in many directions	Scope
11	In places like that there are few boundaries to limit my possibility for moving about	Scope

Table 3

Ad hoc items assessing the six Basic Global Properties of the image

Global Property	Item
	We ask you to look at the following pictures and answer the questions. To choose your answer, select only one of the numbers on the scale next to each statement. The scale ranges from a minimum score of 1(= not at all), to a maximum score of 7 (= very much)
Openness	How wide is the scene you see?
Expansion	How much does the scene you see look three-dimensional?
Depth	How far can you see into the distance?
Transience	If you were inside the scene, how much movement would you perceive?
Concealment	If you were inside the scene, how much could you hide or take cover?
Navigability	If you were inside the scene, how freely could you move?

Table 4

Items used to assess the perceived restorativeness of images by the pairwise comparison method

We ask you to compare these two images and indicate:	
DIMENSION:	ITEM:
FASCINATION: the scene effortlessly draws the attention	Which one draws your attention more?
BEING AWAY: the scene generates a sense of feeling away from daily worries	Which would you most like to temporarily escape from your everyday reality?
COHERENCE: there are order and harmony among the elements in the scene	In which one is there more harmony between the present elements?
SCOPE: the scene generates the perception of being able to explore it	Which one can you explore more?

Table 5

Items used to assess the basic global properties of the scene by the pairwise comparison method

We ask you to compare these two images and indicate:	
DIMENSION	ITEM
OPENNESS	In which one is the scene wider?
EXPANSION	Which one has the most perspective
DEPTH	In which one do you see the farthest?
Imagine now that you are inside the scene, between these two images:	
TRANSIENCE	In which there is more movement?
CONCEALMENT	In which do you feel most exposed (e.g., to the sun, weather, and natural agents in general)?
NAVIGABILITY	In which do you move most freely?

Table 6

Images' restorativeness scores assessed on 7-point Likert Scale

ID IMAGE	FASCINATION	BEING AWAY	COHERENCE	SCOPE
id_19	5.97	6.12	5.87	6.18
id_31	3.68	3.82	4.57	4.5
id_35	3.63	3.94	4.45	4.45
id_41	5.22	5.15	3.49	4.88
id_45	3.34	3.17	4.11	4.08
id_47	4.24	4.38	4.89	5.06
id_94	5.57	5.61	5.5	5.33
id_96	5.09	5.56	5.44	5.58

Table 7

Images' BGPs scores assessed on 7-point Likert Scale

ID IMAGE	OPENNESS	DEPTH	EXPANSION	TRANSIENCE	CONCEALMENT	NAVIGABILITY
id_19	6.07	5.79	5.61	4.61	4.54	6.02
id_31	5.96	5.35	4.24	4.25	3.38	5.85
id_35	3.34	2.32	3.15	3.09	1.6	5.06
id_41	3.24	2.82	4.75	4.11	4.04	3.43
id_45	3.72	3.52	3.86	4.51	4.6	4.45
id_47	4.52	3.96	4.93	3.79	3.74	5.09
id_94	4.37	3.77	5.15	5.14	4.49	4.51
id_96	4.74	4.47	5.02	4.09	4.51	5.29

Table 8

Images' restorativeness scores assessed on a dichotomous scale with the pairwise comparison method

ID IMAGE	FASCINATION	BEING AWAY	COHERENCE	SCOPE
id_19	1.98	2.00	1.49	1.49
id_31	0.01	0.10	0.38	0.16
id_35	0.00	0.40	0.30	0.10
id_41	0.96	1.20	0.63	0.71
id_45	0.27	0.00	0.00	0.00
id_47	0.20	0.44	0.41	0.49
id_94	1.59	1.68	1.36	0.99
id_96	1.17	1.39	1.14	1.15

Table 9

Images' BGPs scores assessed on a dichotomous scale with the pairwise comparison method

ID IMAGE	OPENNESS	DEPTH	EXPANSION	TRANSIENCE	CONCEALMENT	NAVIGABILITY
id_19	2.51	2.89	2.05	0.58	1.10	2.12
id_31	2.22	2.43	1.03	0.32	1.19	1.48
id_35	0.77	0.30	0.00	0.00	1.05	1.53
id_41	0.00	0.00	0.72	0.77	0.00	0.00
id_45	0.68	0.94	0.48	1.12	0.82	0.55
id_47	1.01	1.19	1.13	0.29	0.20	1.08
id_94	1.25	0.85	1.13	1.46	0.30	0.54
id_96	1.15	1.81	1.56	0.52	0.02	1.59

Table 10

Kendall's Tau values obtained by comparing the two methods of measuring restorativeness dimensions

Pairwise Comparison Scores	Likert Scores				
	FASC.	B.A.	COH.	SCO.	OVERALL PR
FASCINATION	.71				
BEING AWAY		.86			
COHERENCE			.71		
SCOPE				.93	
OVERALL PR					.86

Table 11

Kendall's Tau values obtained by comparing the two methods of measuring BGPs

Pairwise Comparison Scores	Likert Scores					
	OPEN.	EXP.	DEPTH	TRANS.	CONC.	NAV.
OPENNESS	.79					
EXPANSION		.64				
DEPTH			.36			
TRANSIENCE				.71		
CONCEALMENT					- .07	
NAVIGABILITY						.71

Table 12

Correlation analysis between the four dimensions related to perceived restorativeness (i.e., fascination, being away, coherence, and scope) and the four basic global properties of a scene/image (i.e., openness, expansion, transience, and navigability)

	OPENNESS	EXPANSION	TRANSIENCE	NAVIGABILITY
FASCINATION	0.18	0.17	0.26*	0.39***
BEING AWAY	0.19	0.10	0.16	0.32**
COHERENCE	0.28**	0.14	0.13	0.37***
SCOPE	0.41***	0.33***	0.33**	0.65***

Figure 1

Direct Effects of Structural and Functional BGPs on Fascination

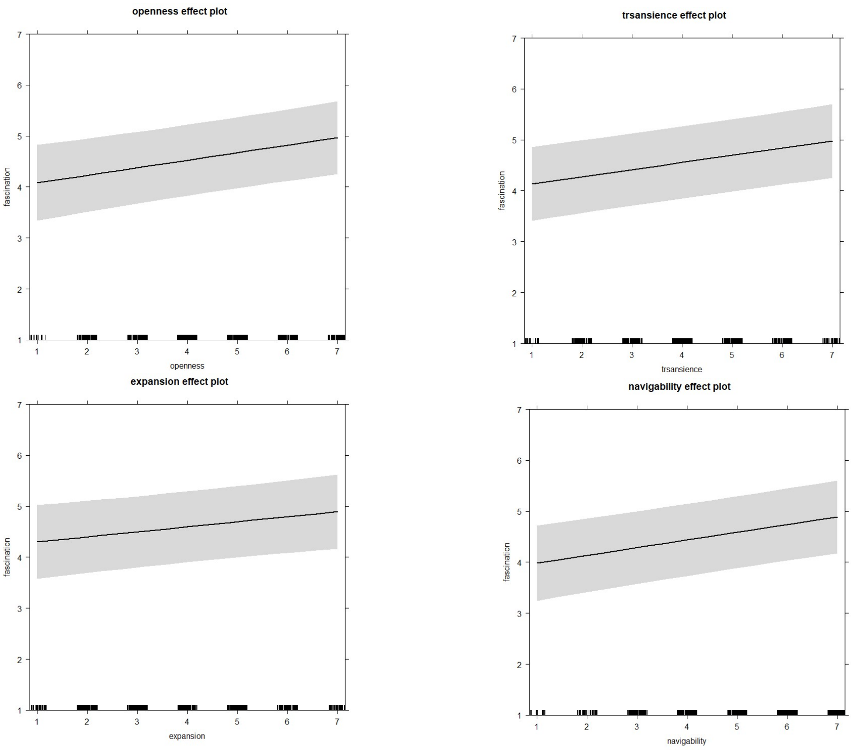


Figure 2

Direct Effects of Structural and Functional BGPs on Being Away

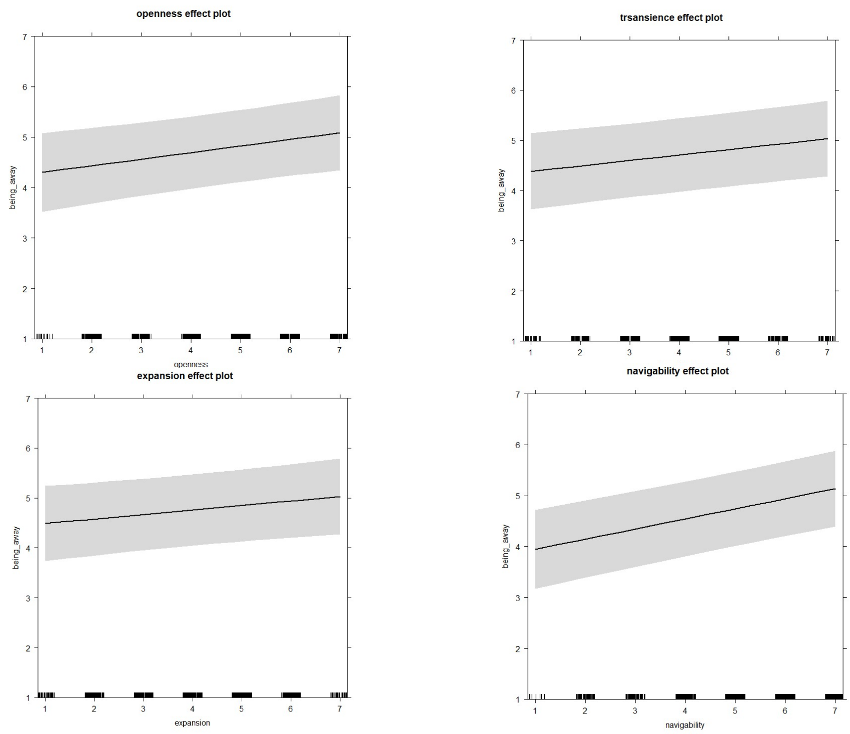


Figure 3

Direct Effects of Structural and Functional BGPs on Coherence

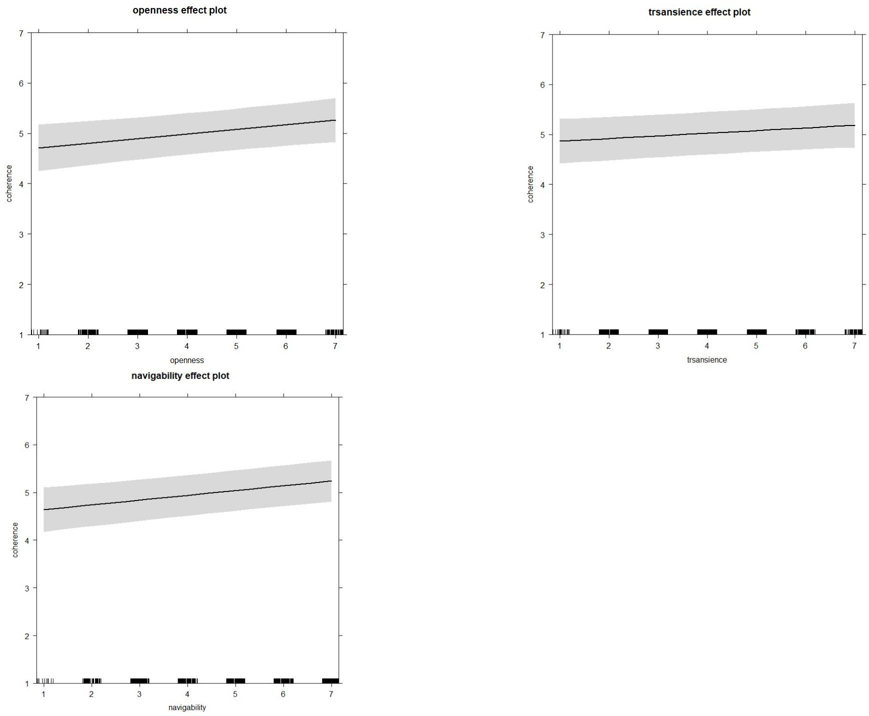


Figure 4

Direct Effects of Structural and Functional BGPs on Scope

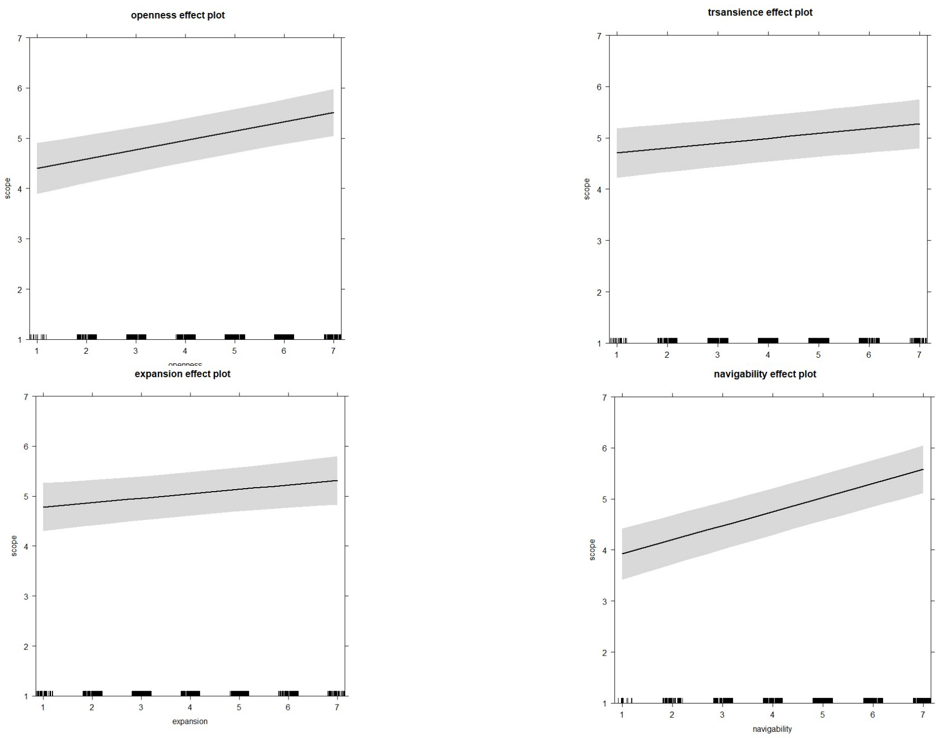


Figure 5

Interaction Effects of Openness and Expansion on Scope

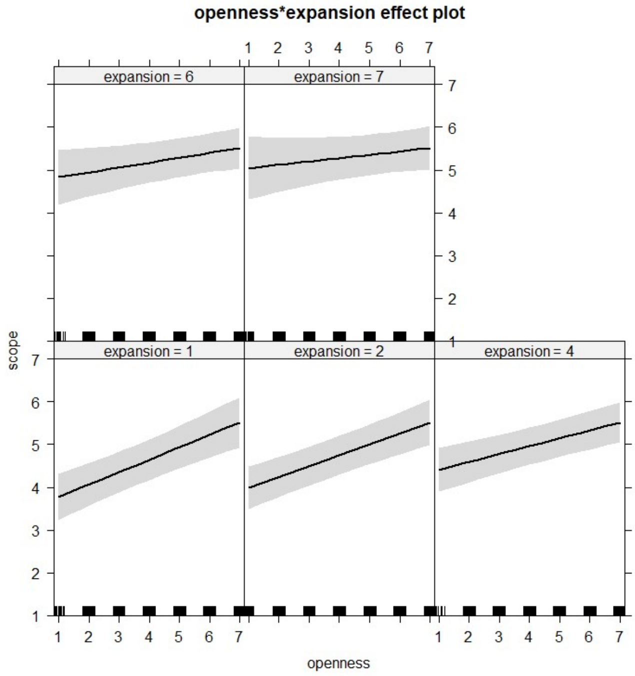
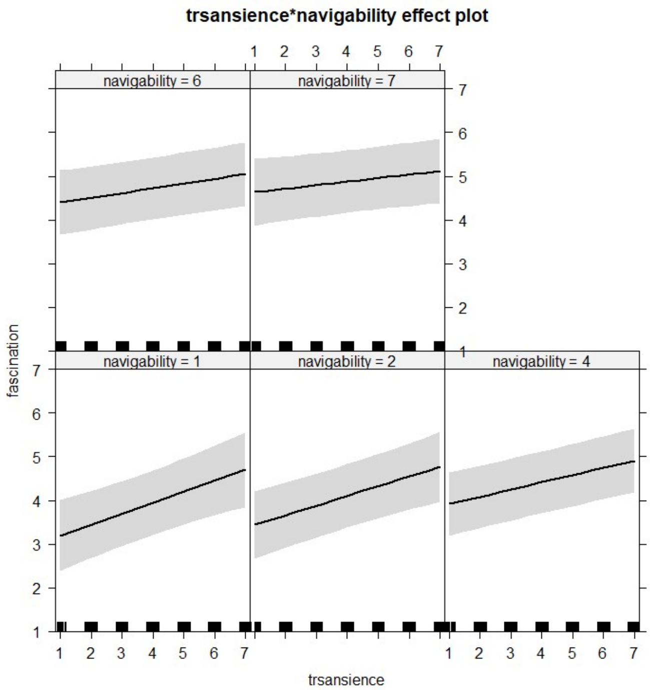


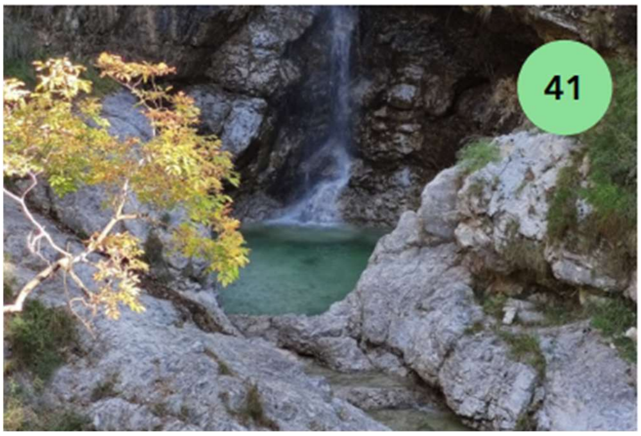
Figure 6

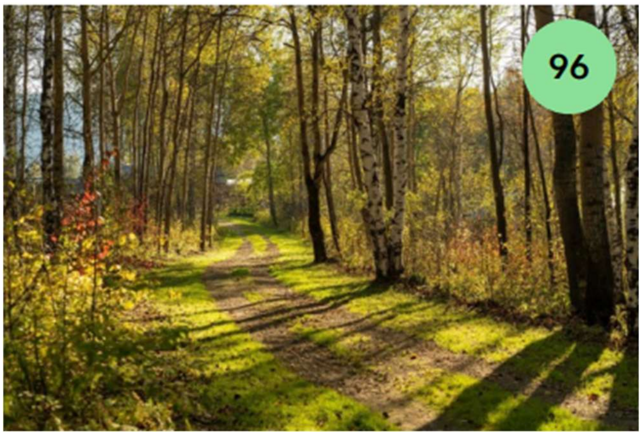
Interaction Effects of Transience and Navigability on Fascination



Appendix B

The eight natural images used in Study 1 and Study 2. The four images marked with the green dot are those with high PR levels, whereas, those with the red dot are those with low PR levels




96


31


35


45


47

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CONTRIBUTION 3:
PERCEIVED RESTORATIVENESS: A MULTIDIMENSIONAL FRAMEWORK FOR ENVIRONMENTAL RESTORATION

ABSTRACT

The perception of restorativeness (PR) has been widely investigated within environmental psychology, with theories such as Attention Restoration Theory (Kaplan & Kaplan, 1989), Stress Recovery Theory (Ulrich, 1991), and Gestalt principles of perceptual organization (Bozzi, 1989; Kimchi et al., 2007) providing key conceptual frameworks. Building on these perspectives, the present study explores the hypothesis that PR emerges from the integration between some Basic Visual Features (BVFs), which, in turn, generate the Basic Global Properties (BGPs) of the scene, understood as structural visual characteristics that support the perception of environmental restorativeness. A two-part experimental study was conducted. In Study 1, a sample of 21 participants evaluated eight BVFs (e.g., linear perspective, symmetry, chiaroscuro) across 12 natural landscape images using a rank-order method. Cluster analyses were employed to group BVFs into four BGPs (i.e., openness, expansion, complexity, texture) and to categorize images accordingly. In Study 2, 102 participants evaluated the same images for PR using a Likert scale. Mixed-effects models revealed that clusters of images differing in BGPs significantly predicted variations in perceived restorativeness and its subdimension of fascination. In particular, scenes characterized by expansion and complexity were rated as significantly more restorative than those with minimal structural organization. These findings demonstrate that restorative potential is not exclusive to natural scenes, but rather emerges from specific visual-structural configurations. The study offers practical implications for the design of built environments - such as public spaces, urban gardens, and interiors - suggesting that integrating perceptually meaningful visual features can enhance psychological well-being and promote restorative experiences.

Introduction

Restorative Environments (REs) are physical contexts that promote psychological well-being by facilitating emotional and cognitive recovery (Hartig, 2004; Kaplan & Kaplan, 1989). Studies consistently demonstrate that exposure to REs reduces stress, improves attention, and enhances feelings of calm and relaxation (Sharam et al., 2023; Ojala et al., 2023; Mattila et al., 2020). These benefits highlight the importance of Perceived Restorativeness (PR), a critical construct for understanding the environmental characteristics linked to REs. Investigating the factors that determine PR is essential to identifying which physical properties make an environment restorative. Dimensions such as fascination, being away, coherence, and scope are particularly significant in this context (Kaplan & Kaplan, 1989; Hartig et al., 1997). These dimensions emerge from the interaction between perceptual and functional characteristics of environments, suggesting that restorativeness is not the result of isolated attributes but a holistic combination of properties (Tang et al., 2017; Pals et al., 2014).

This study adopts an integrated, multiperspective approach to deepen the understanding of PR. It combines Gestalt theories of perception (Bozzi & Longo, 1989; Kimchi et al., 2016), research on visual attention mechanisms (Treisman & Gelade, 1980; Wolfe, 1994, 2021), and the psychophysical perspective (Oliva & Torralba, 2002; Greene & Oliva, 2009). Specifically, the research explores how basic visual features (BVFs) and basic global properties (BGPs) shape the restorative qualities of an image. By integrating different perspectives, the study aims to provide new insights into how both natural and human-made spaces can be optimized to maximize their restorative potential.

1.1. Theoretical Foundations and Key Aspects of Perceived Restorativeness

Perceived restorativeness (PR) is the feeling of emotional and cognitive recovery that humans experience when they encounter physical environments with certain characteristics that are called restorative environments (REs). Within environmental psychology, PR has become a critical construct in understanding how environmental physical features influence the perception of well-being (Hartig, 2004). Indeed, REs are associated with positive outcomes across emotional and cognitive domains. For instance, exposure to REs, whether real or virtual, enhances positive emotions such as calmness and relaxation (Evensen et al., 2017; Jahncke et al., 2011; Tsunetsugu, Park & Miyazaki, 2010; Barton & Pretty, 2010) and improves cognitive functions, including concentration, working memory, and problem-solving abilities (Bauman et al., 2023; Ojala et al., 2023; Grahn & Stigsdotter, 2010; Wang & Taylor, 2006). Furthermore, REs increase individuals' resilience to stress and the ability to manage challenging situations (Brown, Barton & Gladwell, 2013; Pheasant et al., 2010; Ulrich et al., 1991). Research is still investigating which features in REs generate PR. While natural environments consistently elicit higher levels of PR, compared to built ones, studies suggest that certain human-made settings can also have significant restorative potential. Researchers have shown that natural landscapes with water features, dense vegetation, or expansive views often evoke higher levels of PR due to their alignment with evolutionary preferences for resource-rich and non-threatening environments (Wilson, 1984; Kaplan & Kaplan, 1989). However, urban settings designed with aesthetic and structural appeal, such as the night skyline of New York City or architecturally rich public spaces, can also provide restorative experiences (Lee et al., 2022; Scopelliti et al., 2019; White et al., 2010). These findings indicate that it is not the mere presence of natural elements but rather the holistic combination of perceptual and functional characteristics that contributes to the emergence of PR in REs (Tang et al., 2017; Pals et al., 2014).

These results suggest that further research is necessary to identify the underlying mechanisms and specific features that maximize the restorative potential of both natural and built environments.

Several theoretical frameworks have been proposed to explain the mechanisms underlying PR. The Biophilia hypothesis (Wilson, 1984) posits that humans have an innate affinity for natural environments, shaped by evolutionary processes. This hypothesis suggests that specific features of natural landscapes, such as open spaces, the presence of water, and vegetation, signal safety and resource availability, eliciting positive emotional responses. Building on this foundation, Stress Recovery Theory (SRT; Ulrich, 1983; Ulrich et al., 1991) highlights the role of natural landscapes in generating immediate emotional benefits, such as reduced physiological arousal and increased positive affect. On the other hand, the Attention Restoration Theory (ART; Kaplan & Kaplan, 1989; Kaplan, 1995) emphasizes cognitive mechanisms, proposing that natural environments effortlessly attract attention (termed "soft fascination") and allow the recovery of directed attention capacity, which is often depleted in urban settings. Complementarily, the Perceptual Fluency Account (Joye & van den Berg, 2018) associates restorativeness with the perceptual ease of processing environmental features, such as fractal patterns and redundancy, which reduce cognitive effort and enhance well-being. Drawing on these theories, the construct of PR has been operationalized with four core dimensions that characterize REs:

- *Fascination* refers to the ability of REs to capture attention effortlessly and promote aesthetic appreciation. Fascination arises from features that inspire wonder and admiration, such as natural landscapes, architectural landmarks, or artistic compositions (Kaplan, 1995). Environments high in fascination often evoke a sense of surprise and delight, drawing individuals into a state of contemplation and immersive engagement (Herzog et al., 1997).
- *Being Away* pertains to the psychological sense of escape from routine and demanding environments. Hight being away environments provide a context that contrasts with daily life, often characterized by novelty or unique features that stimulate imagination and encourage mental detachment from stressors (Kaplan, 1995; Hartig et al., 1997).
- *Coherence* is the degree to which REs’ elements are perceived as orderly, harmonious, and meaningful. Environments with high coherence facilitate cognitive processing by presenting a clear

and structured layout, enhancing predictability and ease of navigation (Kaplan & Kaplan, 1989; Herzog et al., 2003).

- *Scope* reflects the perceived potential for exploration and discovery within a physical space. High-scope environments, such as expansive landscapes or urban parks, invite curiosity and movement while minimizing barriers or perceived threats (Hartig et al., 1997; Kaplan, 1995).

Looking at the dimensions of PR, it is important to note that the sense of restorativeness is not merely the result of isolated features but emerges from the interaction of structural and functional environmental properties. Drawing on Gestalt-inspired theories, particularly those articulated by Bozzi (1989; 1998; 1999), we can hypothesize that PR and its associated dimensions constitute "emergent qualities" (i.e., tertiary qualities) of one environment. According to Bozzi (1989; 1999), the concept of tertiary qualities refers to the immediately experienced qualities of an object or environment that evoke affective reactions in the observer. These qualities are neither solely attributes of the object nor projections of the observer but are emergent properties arising from the interaction between the two (Bozzi, 1989; 1998; Sinico, 2020; 2025). According to Biassoni et al. (2023), tertiary qualities are pivotal in the context of REs. Indeed, the four dimensions of PR - fascination, being away, coherence, and scope - can be conceptualized as tertiary qualities, as they emerge from the dynamic interaction between environmental features and human perceptual-affective systems. Actually, when an environment, such as a lush forest or an architecturally significant urban square, is perceived as restorative, this is due to its expressive qualities signaling messages like "relax," "explore," or "recover". Future research should continue to investigate how specific environmental features contribute to these tertiary qualities and, in turn, enhance restorativeness. This inquiry could bridge phenomenological perspectives with empirical studies, advancing our understanding of how perceptual-affective interactions with the environment support psychological well-being.

1.2. What Generates the Tertiary Qualities of an Environment?

Conceptualizing PR dimensions as tertiary qualities of an environment, this study aims to shed light on what basic physical features in REs contribute to generating PR, integrating studies on attentional-perceptual visual mechanisms, gestalt theories, and the psychophysical perspective.

Feature Integration Theory (FIT; Treisman and Gelade, 1980; Treisman and Gormican, 1988) posits that when the human visual system encounters a stimulating configuration (i.e., an external world environment), it is not immediately capable of simultaneously processing all the contained in items. To allow for a coherent and meaningful perception of the external environment, visual attention is rapidly and automatically drawn to some basic features (e.g., items' color, spatial orientation, and frequency). The "aggregation" of these basic features enables a quick, albeit coarse, idea of the environment the subject is in. Following this initial representation, which occurs through automatic attentional processes, the subject can direct voluntary attention processes toward the most relevant elements to achieving his or her goals, thereby forming a more precise understanding of the environment. The idea that visual attention is essentially "feature-based" (i.e., attracted by certain basic items or relationships between items in the stimulating configuration) is supported by research inspired by gestalt concepts and studies on the functioning mechanisms of visual attention. Drawing on Gestalt theories, various experimental studies have shown that certain basic features and their relationships (e.g., closure, similarity, collinearity, parallelism between items) are exploited by the visual system as 'clues' to perceive coherent objects within a set of visual stimuli and, when a coherent object emerges, visual attention is immediately drawn to it (Kimchi, Yeshurun, and Cohen-Savransky, 2007; Kimchi, Yeshurun, Spehar, and Pirkner, 2016). Recent studies by Wolfe on visual search tasks have also demonstrated that the increasing of the number of distractors does not slow down the search task if the target possesses salient basic features that rapidly and automatically draw visual attention (Wolfe, 1994; 2021).

These findings suggest that when the human visual system encounters a set of external stimuli, it is drawn to certain basic features that enable a quick and global representation of the environment. Within the realm of REs, the Scene-Centered Approach (Oliva and Torralba, 2002; Greene and Oliva, 2009) asserts that, in distinguishing between natural and built environments, humans rely on basic global properties (BGPs) of the environment. BGPs refer to fundamental perceptual characteristics of a scene derived from basic or low-level visual features. BGPs operate in the early stages of vision, by aggregating basic visual features such as lines, edges, and contours. They enable a rapid and global understanding of the scene and allow individuals to quickly and intuitively recognize the structure, meaning, and function of their environment. BGPs play a key role in shaping the perceptual experience. Specifically, according with Oliva & Torralba (2002), to understand the structure of one environment, the relevant BGPs are:

- *Openness*. It represents how spacious and unrestricted a scene appears. High openness environments allow the gaze to move freely across the panorama without obstruction. Typically, such environments include a clear and unobstructed horizon line, separating the earth from the sky, with minimal foreground features like buildings interrupting the view. These qualities create a sense of freedom and ease in the visual experience.
- *Expansion*. It refers to the perspective of a scene, characterized by parallel lines converging at a central vanishing point. This configuration draws the observer's gaze towards the center, offering a sense of distance and perspective. High expansion is evident in environments composed of long, straight paths or mountain trails, where elements guide attention into the depth of the image, emphasizing direction and potential exploration.
- *Depth*. It conveys the three-dimensionality of a scene. It emerges from the arrangement of elements across multiple perspective planes, with larger features in the foreground and smaller ones receding into the background. This organization creates the perception of significant spatial distance and immerses the viewer in the scene, enhancing the feeling of visual richness and complexity.

Aligning with the literature that has studied the global properties of a physical environment (Roberts, Schira, Spehar & Isherwood, 2022; Lavdas & Schirpke, 2020; Viengkham, Isherwood & Spehar, 2022), an additional global property can be included with those listed by Oliva & Torralba (2002), namely:

- *Complexity*. By the term complexity, we mean the aggregation of basic geometric elements that makes the environment rich and stimulating, but at the same time orderly. An example of complexity is provided by fractals (Robles, 2023). Fractals are geometric elements that are repeated over various orders of magnitude. Fractals are found in nature (e.g., the shape of ferns or other tree leaves, ice crystals) but are also reproduced in man-made architectural works (e.g., capitals and flying buttresses in Gothic cathedrals).

The BGPs of an environment are thus basic global structural characteristics that enable individuals to quickly understand the type of environment they are in. However, BGPs themselves result from the combination of basic visual features (BVFs), which operate according to the roles of vision identified by Gestalt theories.

Referring to pictorial cues (i.e., the "tricks" used by painters to represent three-dimensional spaces on a two-dimensional plane), for each of the BGPs mentioned above, we can identify BVFs that, when combined, generate the global sense of openness, expansion, depth, and complexity. Specifically, in a scene, *openness* is determined by:

- *Visibility of the horizon line*. In an image, the horizon line is the line that ideally separates the sky from the ground. The straighter, more continuous, and less obstructed the horizon line is, the greater the impression of environmental openness.

- *Height of the horizon line*. This BVF relates to the relationship between the figure (i.e., elements in the foreground) and the background. The lower the horizon line in an image, the fewer foreground elements are visible, and the greater the sense of openness in the environment.

The sense of *expansion* is determined by:

- *Linear perspective*. Linear perspective is created when an image contains multiple straight lines converging toward a single vanishing point. The greater the linear perspective, the greater the perceived distance between the observer's viewpoint and the farthest point in the scene (i.e., environment with significant expansion).

- *Aerial perspective*. Aerial perspective in an image is conveyed through the presence of fully focused elements in the foreground and less focused elements in the background. Since we know that air is not completely transparent and creates a barrier that makes distant objects appear "faded" compared to those in the foreground, this cue also enables us to perceive a great distance between our viewpoint and the farthest point visible in the scene (i.e., an environment with high expansion).

Depth primarily depends on:

- *Texture gradient*. This arises from the relationship between the elements in the scene. Images with a high texture gradient feature large elements in the foreground that progressively decrease in size in the background, providing a strong sense of depth to the scene.

- *Light and shadow (i.e., Chiaroscuro)*. Chiaroscuro is also determined by the relationship (i.e., contrast) between lighter and darker parts of the image. Chiaroscuro adds three-dimensionality to the image and enhances the sense of depth in an environment.

Complexity is determined by:

- *Symmetry*. In an image, high symmetry occurs when, by ideally dividing the image into two parts, horizontally or vertically, the two parts are mirrored. For example, images depicting water surfaces, where elements on land are reflected in water, are highly symmetry.

- *Collinearity*. High collinearity occurs when the image is composed of a considerable number of straight lines that continue parallel vertically, horizontally, or obliquely.

Given the above, in this study, we hold that BVFs of an environment, such as the visibility and height of the horizon line, linear and aerial perspective, texture gradient, chiaroscuro, symmetry, and collinearity, significantly contribute to the perception of the BGPs' openness, expansion, depth, and complexity. These properties, in turn, directly influence PR by supporting its core dimensions: fascination, being away, coherence, and scope. For example, environments with high openness, derived from BVFs such as a visible and low horizon line, will promote a greater sense of "being away" and coherence. Scenes with marked expansion, determined by linear and aerial perspective, will enhance fascination and exploratory curiosity (i.e., scope). Furthermore, environments with accentuated depth, created by texture gradient and chiaroscuro, will be perceived as immersive, improving fascination and the feeling of scope. Finally, high-complexity images will turn out stimulating and at the same time ordered, arousing fascination, a sense of security, and a desire to explore the surroundings (i.e., scope).

This hypothesis suggests that the perception of restorativeness emerges from the combination of basic visual features and global properties, acting as elements that support PR tertiary qualities (i.e., fascination, being away, coherence, and scope). Conceptualizing PR as a tertiary quality, resulting from the integration between BVFs (i.e., physical items) and BGPs (i.e., the way physical items are aggregated by the visual system), leads to a better understanding of why natural but also built environments can appear restorative. Indeed, as argued by the SCA, scenes of natural environments, compared to built environments, tend to have greater openness, expansion, depth, and complexity, but built environments can also be designed to have high levels of environment-structural BGPs. For example, a typical restorative landscape is composed of a forest path lined with trees (i.e., high expansion, itself determined by high linear perspective, chiaroscuro, and collinearity). These characteristics of a natural environment can be reproduced in a town square by constructing lines that guide the gaze towards a vanishing point (i.e., high linear perspective and collinearity) and by using materials that allow 'relations' of chiaroscuro. Another typical regenerative image is provided by an alpine landscape (i.e., mountains and trees) reflected in a lake. The structure of this environment, composed of high complexity (i.e., high symmetry and collinearity) can be reproduced in the structure of an urban building by designing parallel lines and symmetrical elements.

1.3. Aims

Building on the theoretical frameworks and empirical findings discussed above, this study hypothesizes that the perception of restorativeness (PR) emerges from the integration between some basic visual features (BVFs), which, in turn, generate the basic global properties (BGPs) of an image. This relationship is supposed to be the basis of the perceptual-affective processes underlying tertiary qualities in a REs. Specifically, the following can be hypothesized:

H1: BVFs, such as the visibility and height of the horizon line, linear and aerial perspectives, texture gradients, chiaroscuro, symmetry, and collinearity, significantly influence the perception of the BGPs openness, expansion, depth, and complexity in an image;

H2: BGPs have a direct effect on PR by supporting its core dimensions: fascination, being away, coherence, and scope.

This framework emphasizes the hierarchical interaction between BVFs and BGPs in generating tertiary qualities, advancing our understanding of how environmental features elicit restorative experiences and promote psychological well-being. It will also be possible to better understand how BVFs, integrating with each other, generate BGPs, and which of the BGPs contribute most to the perception of restorativeness.

Method

To test our research hypotheses (H1 and H2), we designed and conducted a two-part experimental study utilizing a set of 12 images depicting various natural environments (see Appendix A). Each part of the study involved distinct participant samples, measurement techniques, and data analysis strategies, designed to address specific research questions concerning the relationship between low-level visual features and higher-order perceptual responses. Study 1 concentrated on the perceptual assessment of Basic Visual Features (BVFs) embedded in the images using a rank-order judgment method, whereas Study 2 involved the subjective evaluation of Perceived Restorativeness (PR) through a structured Likert-scale instrument. The choice to divide the study into two independent phases was driven by methodological concerns, particularly the need to minimize participant fatigue, improve data reliability, and tailor the measurement technique to the specific characteristics of the constructs under investigation.

2.1. Study 1 – Evaluation of Basic Visual Features (BVFs)

For the evaluation of the BVFs in each of the 12 selected images, the rank-order method was used. This method involves simultaneously presenting the entire set of stimuli (i.e., the 12 images) to participants and asking them to rank the images based on the intensity of each investigated BVF, from the least to the most evident. Each stimulus/image thus receives a rank for each BVF, reflecting its relative position compared to the others. This method relies on multiple comparisons and comes with advantages and disadvantages compared to another well-known ranking method, like, for instance, the pairwise comparison method. The latter involves presenting the stimuli/images in pairs, two at a time, to evaluate the investigated properties. Compared to the pairwise comparison method, the rank-order method is faster, since all stimuli are presented simultaneously to participants, but it is also more complex when the number of stimuli is large. In such cases, participants might adopt subgrouping strategies, introducing artifacts into their responses. To mitigate this risk, it was deemed appropriate not to expand the set of stimuli/images beyond 12 examples. The obtained ranks of the stimuli/images are usually transformed, first, into z-scores and then into scalar scores, to obtain a quantitative measure of the stimuli/images characteristics under investigation. The rank-order method was deemed particularly suitable for measuring BVFs for the following reasons:

- It simplifies the evaluation task. The method allows participants to evaluate all stimuli/images simultaneously, providing a direct reference (i.e., the other stimuli in the set) that simplifies the judgments;
- It reduces the risk of response biases. Unlike evaluations on Likert scales, the rank-order method reduces biases such as central tendency or extreme responses, as participants must compare stimuli relatively, rather than assigning absolute values;
- It promotes detailed judgments. The availability of the entire set of stimuli simultaneously, compared to evaluating a single stimulus, encourages more detailed judgments, even when differences between stimuli are nuanced;
- Compared to other ranking methods (e.g., pairwise comparison), it ensures better time efficiency. Although comparing multiple stimuli requires time, the rank-order method is still faster than approaches like pairwise comparison, where participants must evaluate all possible pairs of available stimuli one by one.

2.1.1. Participants

Study 1 was conducted with a sample of 21 participants (mean age = 25 years, SD = 2.73), of whom the majority were female (90.48%). All participants were enrolled in psychology courses at the University of Verona and were recruited through in-class announcements. Participation was voluntary, and no financial compensation was offered. All participants provided informed consent prior to participation.

2.1.2. Materials

The stimulus set consisted of 12 color photographs selected from a larger repository of over 100 images representing natural landscapes. The selection criteria ensured sufficient variability across the target BVFs, such as variations in horizon line visibility, structural perspective, texture richness, and compositional features. Each image was printed on 10 x 13.5 cm cardstock and presented in either horizontal or vertical orientation, with equal distribution across the two formats. Half of the images included water elements (e.g., lakes, rivers, waterfalls), while the other half depicted exclusively green natural elements (e.g., forests, meadows, hills). Images were standardized for size and resolution to prevent confounding effects due to visual saliency or framing differences.

2.1.3. Procedure

Part 1 of the study was conducted in the laboratory, with the presence of an experimenter. Participants were brought into the laboratory in groups of up to six people. They were seated at a sufficiently large table to ensure an adequate distance between each participant and to allow the arrangement of the cardboard-printed images. The purpose of the research was briefly explained, along with the data collection procedure, and consent to participate in the research was collected.

After this preliminary phase, the experimenter projected on a screen a prototypical image regarding the first BVF that needed to be evaluated (e.g., visibility of the horizon line). The image depicted a natural landscape and was featured differently from the set of 12 images that participants were to evaluate. The experimenter explained what the investigated BVF consisted of and how to identify it within the image (e.g., for the BVF visibility of the horizon line, it was explained that participants had to identify the line that ideally separates the earth from the sky, and they had to assess whether this line was completely visible or partially or totally obstructed by visual features that overlapped with it) . Following the explanation, the evaluation task was passed to the participants. They were instructed to arrange the images at their disposal, placing them next to each other, from the one with the lowest level to the one with the highest level of the investigated BVF. Once the arrangement was completed, participants recorded the order of the images, each with the corresponding number, in the evaluation grid. When everyone had finished filling out the grid, the experimenter moved on to project another image, prototypical for the next BVF under investigation (e.g., height in the horizon line). A new explanation of the BVF to assess was provided by the experimenter and a new evaluation was done by the participants. The process was repeated until all the BVFs of interest were evaluated. On average, the evaluation of a single BVF took about 8 minutes, including the experimenter's preliminary explanation, the arrangement of the images, and the transcription on the paper grid.

At the end of the evaluation task, demographic information was collected from participants, they were asked if they encountered any difficulties with the task, and the experimenter remained available for any questions or clarifications. Overall, participants rated the task as moderately difficult and cognitively demanding. The total duration of the experiment, for each group, was approximately 1 hour.

2.1.4. Analysis overview of Study 1

To explore the structure underlying the BVFs and the images themselves, we conducted two k-means cluster analyses. The first analysis was performed on the BVF variables, with the aim of identifying whether perceptually similar features grouped into clusters aligned with theoretically proposed Basic Global Properties (BGPs), such as openness, expansion, depth, and complexity. Each BVF served as an observation in the clustering process. The second cluster analysis focused on the 12 images as observational units, using the scalar scores obtained from the rank-order procedure for each BVF. The goal was to determine whether the images could be categorized based on their low-level structural configurations. Both clustering procedures used a predetermined number of four clusters (k = 4), consistent with the four BGPs defined in the theoretical framework. The resulting image clusters served as categorical predictors in Study 2.

2.2. Study 2: Evaluation of Perceived Restorativeness (PR) of clusters

In the second part of the study, aimed at evaluating the PR for the same 12 images assessed in Part 1, it was decided to measure the variables of interest through single-image judgment, using a 7-point Likert scale. Unlike BVFs in Part 1, which are often embedded in the overall scene and therefore difficult to isolate and evaluate individually, PR is considered an easier variable to detect in an image. For this reason, the rank-order method was not applied in the second part of the study. Instead, the simpler method of single-image evaluation with a Likert scale was chosen. With this measurement approach, participants were presented with the images one at a time and asked to indicate how much the image possessed the investigated property using a scale ranging from 1 (i.e., the property is not present in the image) to 7 (i.e., the property is maximally present in the image). Compared to the rank-order method, this method of measurement speeds up the evaluation time, reducing overfatigue of experimental subjects and the associated measurement bias.

2.2.1. Participants

The second study involved a separate sample of 102 participants (mean age = 23 years, SD = 8.80), with 72.55% identifying as female. As in Study 1, participants were undergraduate psychology students recruited from the University of Verona, and all took part voluntarily without compensation. Informed consent was obtained from all participants before the start of the experiment.

2.2.2. Materials

The same 12 images used in Part 1 of the study were used in Part 2.

To assess the Perceived Restorativeness (PR) the PRS-11 Scale (Pasini et al., 2014) was utilized. This self-report tool explores the four primary dimensions of restorativeness, as defined by Attention Restoration Theory (Kaplan, 1995). The scale comprises 11 items and represents the Italian adaptation of the Perceived Restorativeness Scale (Hartig et al., 1997). The dimensions examined are:

- Fascination (e.g., item: "In places like this my attention is drawn to many interesting things");
- Being Away (e.g., item: "Places like that are a refuge from nuisances");
- Coherence (e.g., item: "In places like this it is easy to see how things are organized");
- Scope (e.g., item: "That place is large enough to allow exploration in many directions").

The scale is based on the premise that a participant's evaluation of the restorative qualities of an image (i.e., fascination, being away, coherence, and scope) provides a reliable measure of the psychological restorative experience associated with the depicted environment. A summary of the PRS-11 Scale can be found in Supplementary Table 1.

2.2.3. Procedure

This part of the study was conducted in the laboratory, with the presence of an experimenter. Participants were brought into the laboratory in groups of up to ten people. The purpose of the research was briefly explained, along with the unfolding procedure, and consent to participate in the research was collected.

Data collection was managed through the LimeSurvey platform (Limesurvey GmbH 2023). This tool is an open-source online application, accessible through any web browser, that enables fast and automated data collection. Each participant was provided with a workstation consisting of a computer with a 40.6 cm (16-inch) screen. Through the computer, participants accessed LimeSurvey and entered the preliminary section of the survey, where informed consent was collected. Then subjects entered the section of the survey where they were asked to rate the perceived restorativeness of the 12 images presented in Part 1 of the study. The 12 images were presented individually, and participants were asked to respond to the PRS-11 items using a 7-point Likert scale, with the following prompt: "We ask you to look at the following image and answer the questions. To select your answer, mark one of the numbers on the scale next to each statement with a dot. The scale ranges from a minimum score of 1 (= not at all) to a maximum score of 7 (= very much)."

At the end of this second task, participants were asked to provide socio-demographic information (i.e., gender and age). Additionally, they were asked what type of natural environment they most frequently visited in their free time. They could choose from three options: 1. "Wild natural environments (e.g., forests, mountains, beaches)"; 2. "Maintained natural environments (e.g., urban parks, private gardens)"; 3. "Urban nature (e.g., tree-lined streets, courtyards)".

In total, each participant answered 132 items (12 images × 11 items). There was no time limit for completing the survey. The average time required to complete it was approximately 30 minutes. At the end of the task, participants were asked whether they had encountered any difficulties in performing it, and they were given space for any questions or clarification requests related to the research.

2.2.4. Analysis overview of Study 2

The analytical approach involved linear mixed-effects models, used to test whether perceived restorativeness and its subdimensions varied significantly as a function of the image clusters derived in Study 1. The dependent variables included the PRS-11 total score and its four subcomponents. The fixed effect was image cluster (4 levels), while participants were treated as a random intercept to account for repeated measures within subjects. All models were estimated using restricted maximum likelihood (REML), and degrees of freedom were calculated using the Satterthwaite approximation. Model performance was evaluated using marginal and conditional R-squared values, along with intraclass correlation coefficients (ICCs), to assess the proportion of variance attributable to fixed versus random effects. Results of these models are reported in detail in the Results section. Further model details are reported in the Supplementary Materials.

Results

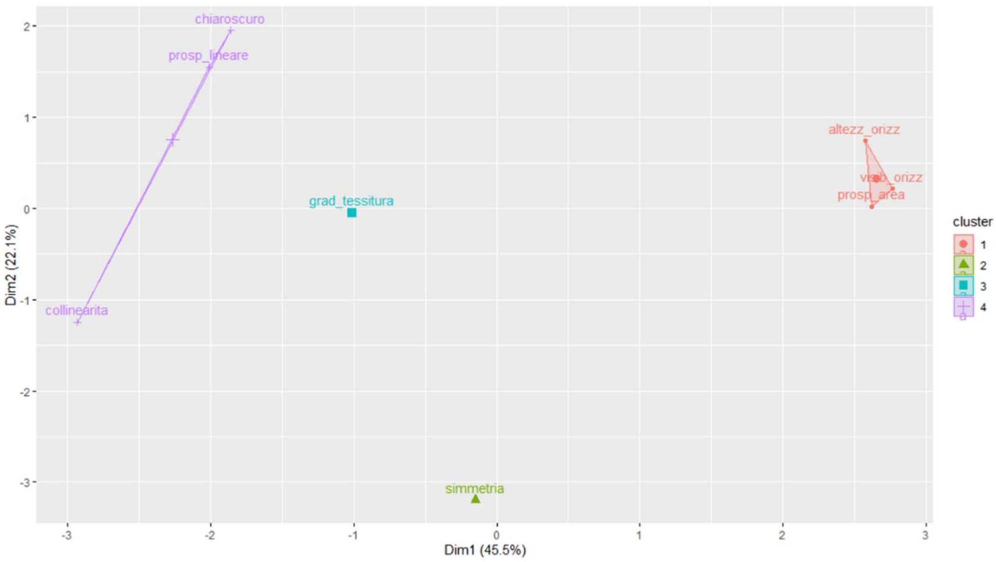
3.1 Study 1

In the first part of the study, we conducted two k-means cluster analyses to explore how a set of basic structural visual properties (BVFs) and their aggregated representation across different images might relate to perceived restorativeness. The aim was twofold: (1) to identify coherent groupings of BVFs that may jointly contribute to global perceptual constructs, and (2) to classify the images based on their perceptual configuration along these BVFs.

3.1.1 Cluster Analysis on BVFs

The first k-means clustering was performed on eight basic structural elements derived from Gestalt and pictorial cue theories: visibility and height of the horizon line, linear and aerial perspective, texture gradient, chiaroscuro, symmetry, and collinearity. The algorithm grouped these properties into four distinct clusters, each interpretable in terms of a broader perceptual configuration, or what we term Basic Global Properties (BGPs) (see Figure 1).

Figure 1 Cluster of BVFs



Cluster 1 (Openness) included horizon visibility, horizon height, and aerial perspective. These features

jointly contribute to the visual experience of openness, enabling a sense of environmental amplitude and sky-ground relation. Cluster 2 (Symmetry) comprised only symmetry, suggesting that this visual element functions as an independent perceptual dimension. Cluster 3 (Texture) consisted solely of a texture gradient, confirming its role as a localized fine-grain property not integrated into structured depth. Cluster 4 (Expansion) grouped linear perspective, chiaroscuro, and collinearity, three cues central to creating depth and directional layout in a scene, thus conveying a strong sense of spatial expansion.

Table 1. Clustering of the eight BVFs and their interpretation

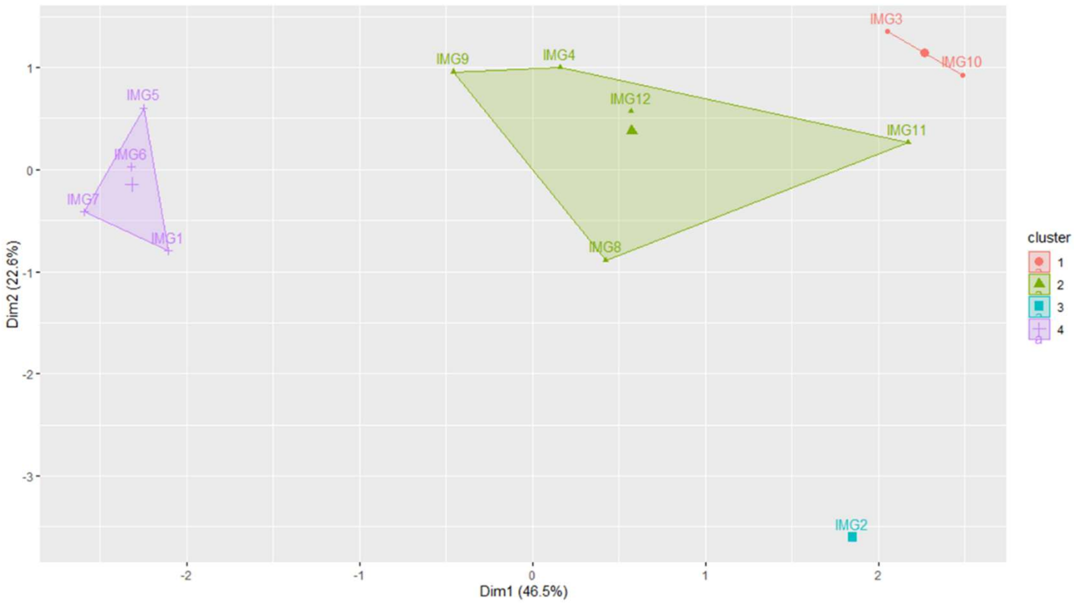
Cluster	BVFs Included	Interpretation (BGP Label)
1	Horizon visibility, horizon height, aerial perspective	Openness - cues related to sky-ground relations
2	Symmetry	Symmetry - isolated perceptual dimension
3	Texture gradient	Texture - fine-grained spatial distribution
4	Linear perspective, chiaroscuro, collinearity	Expansion - structured spatial depth

This analysis supports our hypothesis that BGPs emerge from the integration of specific BVFs, and that these perceptual constructs are functionally distinct. The clustering solution demonstrated excellent compactness and separation, with a between-cluster sum of squares (BSS) of 67.38 and a total within-cluster sum of squares (WCSS) of 11.16. The explained variance reached 85.8%, indicating strong and meaningful groupings.

3.1.2 Cluster Analysis on Images

A second k-means cluster analysis was conducted on the full set of 12 images, based on their rank-order profiles across the eight BVFs. This procedure aimed to group the stimuli according to shared structural characteristics and provide a classification framework for testing perceptual responses in Study 2. Four image clusters emerged (see Figure 2).

Figure 2 Cluster of BGPs



Cluster 1 (Expansion) included IMG3 and IMG10, characterized by high levels of linear perspective (M = 2.97), chiaroscuro (M = 2.58), and collinearity (M = 3.20). These images depict structured scenes with strong compositional directionality and depth. Cluster 2 (Complexity) grouped five images (IMG4, IMG8, IMG9, IMG11, IMG12), showing moderate levels across features but lower scores in symmetry and collinearity, suggesting visually rich yet less orderly scenes. Cluster 3 (Texture) included a single image (IMG2) designed to exemplify a high texture gradient (M = 3.56) with minimal presence of other visual cues. This singleton cluster captured the intended experimental condition of isolated texture. Cluster 4 (Openness) comprised IMG1, IMG5, IMG6, and IMG7, which scored highest on horizon visibility (M = 2.64), horizon height (M = 2.69), and aerial perspective (M = 2.71), while showing low collinearity and chiaroscuro. These images reflect open landscapes with limited internal structure.

Table 2. Clustering of the eight BVFs and their label interpretation

Cluster	Images included	label
1	IMG3, IMG10	expansion
2	IMG4, IMG8, IMG9, IMG11, IMG12	complexity
3	IMG2	texture
4	IMG1, IMG5, IMG6, IMG7	openness

The overall solution explained 68.1% of the variance, with a BSS of 59.97 and a total WCSS of 28.03. While slightly below the 70% threshold typically considered a strong clustering, this result still reflects a moderate and interpretable structure, particularly appropriate for perceptual and psychological data where some degree of overlap is expected.

These findings confirm that the visual scenes used in the experiment differ meaningfully in their structural configuration, and that these differences can be clustered into perceptually and theoretically coherent groups. These image-based clusters were subsequently used in Study 2 to test whether structural configurations, as defined by BGP-related BVFs, significantly influence perceived restorativeness and its subcomponents, particularly fascination.

3.2. Study 2

3.2.1 Mixed model results on PRS

A linear mixed-effects model was computed to test whether perceived restorativeness (PRS) scores varied across the four visual clusters derived in Study 1. The model included image cluster as a fixed effect and participants as a random intercept to account for repeated measures. Model quality indices supported the robustness of the findings. The marginal R^2 was 0.06, indicating the proportion of variance explained by the fixed effect of cluster, while the conditional R^2 was 0.22, reflecting the proportion of variance explained by both fixed and random effects. The intraclass correlation coefficient (ICC = 0.172) suggested a moderate clustering of responses within participants. The model converged successfully and showed a significant main effect of cluster on PRS scores, $F(3, 1119) = 30.90$, $p < .001$. To enhance interpretability, the Texture cluster, characterized by a single image dominated by fine-grained spatial information and minimal structured cues, was selected as the reference category. This allowed a direct evaluation of how other visual configurations differed in perceived restorativeness relative to the texture-dominant scene.

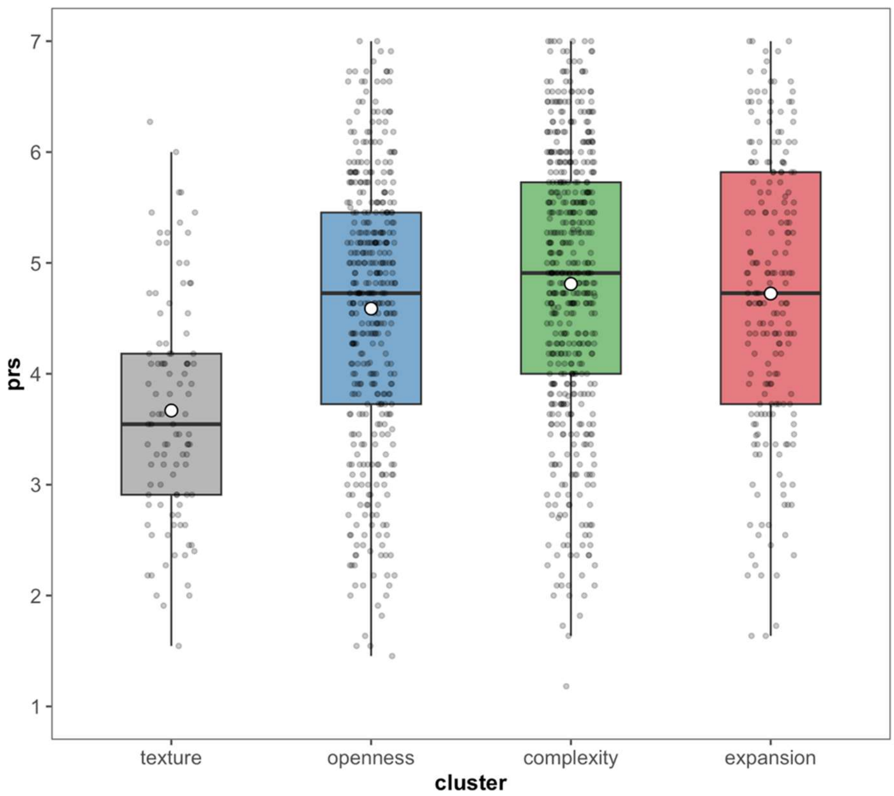
The model intercept, representing the estimated mean PRS score for the Texture cluster, was 4.45 (SE = 0.063, $t = 70.72$, $p < .001$). All other clusters showed significantly higher PR scores when compared to Texture. Specifically, the Complexity cluster was associated with an increase of 1.14 points (SE = 0.120, $t = 9.52$, $p < .001$), the Expansion cluster with an increase of 1.06 points (SE = 0.134, $t = 7.87$, $p < .001$), and the Openness cluster with an increase of 0.92 points (SE = 0.122, $t = 7.51$, $p < .001$). These differences were all statistically significant, as indicated by non-overlapping 95% confidence intervals with zero.

Table 3. Estimated marginal means of PRS total score

				95% CI	
cluster	Mean	SE	df	Lower	Upper
complexity	4.81	0.07	195	4.67	4.95
expansion	4.72	0.09	503	4.54	4.90
openness	4.59	0.07	242	4.44	4.73
texture	3.67	0.12	917	3.43	3.90

Post hoc comparisons with Bonferroni correction were conducted to further examine pairwise differences in PRS scores between the clusters. Results indicated that the Texture cluster, used as the reference category, consistently received significantly lower PRS scores compared to all other clusters. More specifically, images in the Complexity cluster were rated as significantly more restorative than those in the Texture cluster, with a mean difference of 1.14 points (SE = 0.120, $t = -9.52$, $p < .001$). Similarly, the Expansion cluster was associated with a significantly higher PR score relative to Texture, with a mean difference of 1.06 points (SE = 0.134, $t = -7.87$, $p < .001$). The Openness cluster also received a higher restorativeness evaluation, with a significant mean difference of 0.92 points (SE = 0.122, $t = -7.51$, $p < .001$). When comparing the Complexity cluster with the Openness cluster, a small but statistically significant difference emerged. The Openness cluster received slightly higher PR scores than the Complexity cluster, with a mean difference of 0.22 points (SE = 0.073, t = 3.03, p = 0.015). No other contrasts reached statistical significance.

Figure 3. Perceived Restorativeness (PR) scores across image clusters



Boxplots showing the distribution of Perceived Restorativeness scores for each image cluster derived from the k-means analysis. Clusters correspond to distinct Basic Visual Feature profiles (texture, openness, complexity, and expansion). Boxes represent the interquartile range (IQR), the horizontal line inside each box indicates the median, and white dots represent the mean scores.

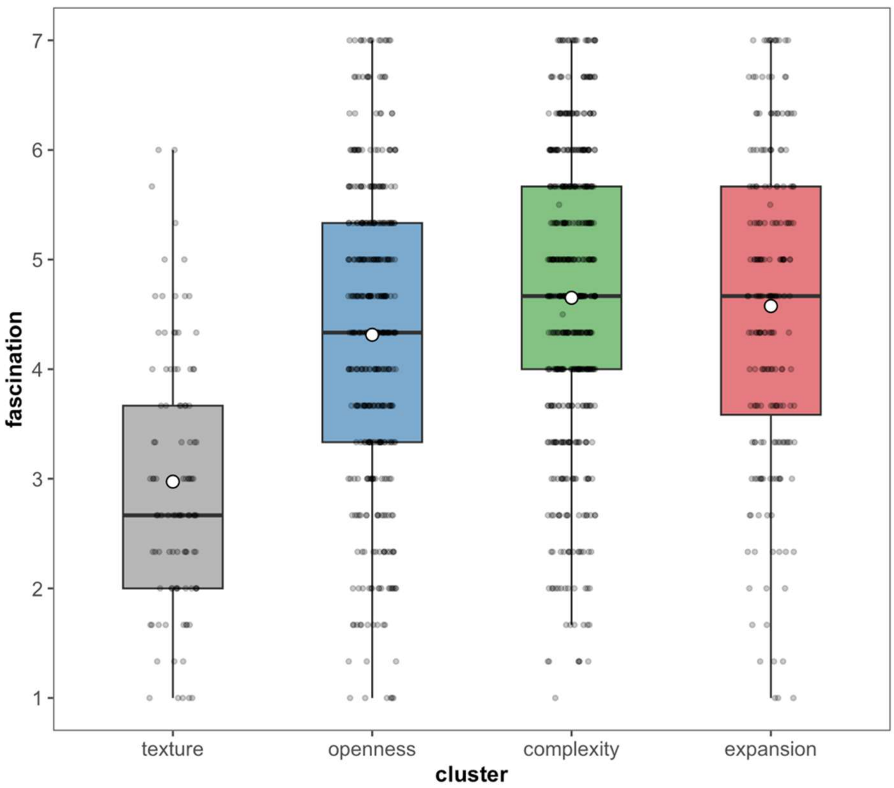
3.3.2. Mixed model results on Fascination

A linear mixed-effects model was conducted to examine whether fascination ratings varied across the four image clusters identified in Study 1. The model included cluster as a fixed effect and participant ID as a random intercept to account for repeated ratings across participants. The model converged successfully and demonstrated good explanatory power, with a marginal R^2 of 0.10 and a conditional R^2 of 0.25. This suggests that approximately 9.6% of the variance in fascination ratings was explained by the image cluster alone, and 24.5% when including both fixed and random effects.

The omnibus F-test for the fixed effect of cluster was statistically significant, $F(3, 1119) = 54.34$, $p < .001$, indicating that the type of visual cluster significantly influenced fascination scores. The fixed effect estimates, using the Texture cluster as the reference category, revealed that all other clusters elicited significantly higher fascination ratings. Specifically, the Complexity cluster showed the largest effect ($b = 1.68$, $SE = 0.1371$, $t = 12.24$, $p < .001$), followed closely by Expansion ($b = 1.60$, $SE = 0.1532$, $t = 10.46$, $p < .001$), and Openness ($b = 1.36$, $SE = 0.1399$, $t = 9.71$, $p < .001$). The intercept, representing the mean fascination score for the texture cluster, was 4.13 ($SE = 0.071$), indicating that images in this cluster were rated substantially lower than those in other groups.

Post hoc Bonferroni-corrected pairwise comparisons further clarified the differences among clusters. Fascination ratings were significantly higher for Complexity compared to Openness (diff = 0.32, $SE = 0.084$, $t = 3.79$, $p < .001$), suggesting a clear preference for visually rich and possibly intricate scenes over more open ones. However, the differences between Complexity and Expansion (diff = 0.075, $p = 1.000$) and between Expansion and Openness (diff = 0.24, $p = 0.149$) were not statistically significant, indicating relative equivalence in fascination between these two types of structured images.

Figure 4. Fascination scores across image clusters



Boxplots showing the distribution of Fascination scores for each image cluster derived from the k-means analysis. Clusters correspond to distinct Basic Visual Feature profiles (texture, openness, complexity, and expansion). Boxes represent the interquartile range (IQR), the horizontal line inside each box indicates the median, and white dots represent the mean scores.

Descriptive estimates of marginal means confirmed these trends: the Texture cluster had the lowest mean fascination score (M = 2.97, 95% CI [2.71, 3.24]), while the Complexity, Expansion, and Openness clusters had substantially higher means of 4.65, 4.58, and 4.33, respectively

Discussion

The study investigates how basic visual features (BVFs) and basic global properties (BGPs) contribute to the perception of restorativeness (PR) in natural scenes. Drawing on Gestalt theory, Attention Restoration Theory (ART), and psychophysical research, we conceptualize PR dimensions (i.e., fascination, being away, coherence, and scope) as tertiary qualities that emerge from the perceptual-affective interaction between the observer's perceptual system and the physical-structural characteristics of the environment. It is hypothesized that the perception of restorativeness is conditioned by the presence in the scene of some global properties inherent in the spatial structure of the environment (BGPs), which, in turn, are derived from the aggregation of some basic visual features (BVFs). In conformity with Gestalt theories (Kimchi, Yeshurun, Spehar & Pirkner, 2016; Kimchi & Peterson, 2008), BVFs are the most basic elements that are grasped by the perceptual system (e.g., relationships between lines, color contrasts, differences in proportions), and BVFs, aggregated together, allow for an overall representation of the scene that the subject faces.

To test the hypothesis, a two-part experimental study was conducted: Study 1 used a rank-order method to assess BVFs (i.e., horizon line height and visibility, linear and aerial perspective, texture gradient and chiaroscuro, symmetry and collinearity) of 12 images of natural scenes. Two cluster analyses, using BVFs (Cluster Analysis 1) and images (Cluster Analysis 2) as grouping units, were conducted to test whether images similar in BVFs grouped according to the different BGPs identified by the Scene Centered Approach (Oliva and Torralba, 2001). Study 2 evaluated PR using Likert scales on the same images. Mixed-model analysis revealed that the different image groupings, clustered according to BGPs, received significantly different PR ratings from each other, confirming that BGPs play an important role in determining perceived restorativeness in a scene.

4.1 The Groupings of the Basic Visual Features according to the Basic Global Properties of the Images

Results from the cluster analyses confirmed that some elementary visual elements of an image (BVFs) tend to be picked up by the human perceptual system and aggregated together to generate representations of scenes that can be differentiated by global properties (BGPs). BGPs provide an overall idea of the environment in which the subject is, informing, for example, whether the environment is more or less broad, deep, or structurally complex, while also suggesting what the subject can do and what he or she cannot do within such an organized environment. Turning to what emerged from our analysis, Cluster Analysis 1, which used BVFs as the grouping unit, returned 4 different clusters. Cluster 1 reflects the BGP Openness. It included 3 BVFs (i.e., horizon visibility, horizon height, and aerial perspective), which maximally contribute to the perception of an open, wide space with no barriers obstructing free movement. Cluster 4 represents the BGP Expansion. It, in fact, clusters the BVFs linear perspective, chiaroscuro, and collinearity that are three central cues to creating depth and directional layout in a scene, thus conveying a strong sense of spatial expansion (i.e., environments in which a great distance between the point where the observer is standing and the farthest visible point in the scene is perceived, suggesting the possibility of exploring the surroundings in depth). Cluster 2 is characterized by high levels of the BVF Symmetry. According to the main theories of drawing, symmetry (i.e., the presence of mirrored parts in the drawing) is a component capable of generating the simultaneous perception of complexity and order (Lavdas & Schirpke, 2020; Viengkham, Isherwood & Spehar, 2022). Complexity is a BGP of the image that suggests to the subject that the environment in which he/she finds himself/herself is full of elements that prompt his/her curiosity and desire for exposition. Cluster 3 (Texture) consisted solely of the BVF texture gradient. Although the texture gradient had been hypothesized as a clue of the BGP Depth, it is more likely that it plays a role of localized fine-grain property, not integrated into structured depth. It is also probable that the BGP Depth constitutes a whole with the BGP Expansion, in fact, Cluster 4 (Expansion) includes the BVF chiaroscuro that was initially hypothesized as a clue of Depth.

Turning to Cluster Analysis 2, which used images as grouping themes, four groups emerged again, mirroring what had already emerged in Cluster Analysis 1. Cluster 4, consisting of IMG 1, 5, 6, and 7, groups images in which the basic global property Openness is high. In this cluster, the visibility of the horizon line and the width of the scene, unobstructed by foreground visual elements, are clearly notable. Cluster 1, comprising IMG 3 and 10, groups scenes with high Expansion; indeed, a central vanishing point (i.e., high linear perspective) determined by straight lines converging to the center of the image is clearly visible. Cluster 2, with IMG 4, 8, 9, 11, and 12, groups scenes that are rich and complex, due to the number of visual elements in them. Due to these characteristics, Cluster 2 can be considered representative of BGP Complexity. Finally, Cluster 3, composed of IMG 2 alone, isolates an image that differs significantly from the others for the absence of the BGPs Openness, Expansion, and Complexity; in fact, it depicts a field of flowers in the foreground, characterized by the sole presence of the BVFs texture gradient. Cluster 3 can thus be considered a kind of condition in which, at the same time, all the main BGPs defining the structural layout of an image are missing.

In conclusion, the two cluster analyses returned four groupings of images differentiated by the BGPs Openness, Expansion, and Complexity. The BGP Depth did not clearly emerge from the clusters, and we believe it can be included in BGP Expansion; in fact, scenes with high linear and aerial perspective tend to generate the sense of expansion and depth simultaneously. These results are in line with numerous studies relying on Gestalt theories, in which it has been shown that, when a subject is presented with a stimulating visual configuration, the perceptual system tends to identify and isolate basic elements (BVFs) and relationships between them (e.g., symmetry, collinearity, contrast, good continuation). These BVFs are then aggregated to generate a representation of the image endowed with sense (Chen, 2000; Kimchi, Razpurker & Apefeld, 2004; Chen & Cave, 2006; Kimchi, Yeshurun & Cohen-Savransky, 2007; Kimchi & Peterson, 2008; Drummond & Shomstein, 2010; Gerhardstein, Tse, Dickerson, Hipp, & Moser, 2012). Other authors who have used the classic psychophysics paradigms (e.g., visual search tasks or texture segmentation tasks) arrived at the same conclusions (Pashler, Dobkins, & Huang, 2004; Poirier, Gosselin, & Arguin, 2008; Richard, Lee & Vecera, 2008; Russel and Driver, 2006; Turatto & Galfano, 2001; Utochkin, Khvostov & Stakina, 2018; Van der Burg, Cass, Theeuwes, & Alais, 2015; Wool, Komban, Kremkow, Jansen, Li, Alonso, & Zaidi, 2015; Zhang, Wan, Jin, & Li, 2017). These results are also in line with the theories of vision that emphasise the importance of a subject quickly representing the structural layout of an environment (e.g., how large, spacious, complex the environment is), in order to understand how to act within it (Oliva & Torralba, 2001; Treisman & Gelade, 1980; Tversky & Hemenway, 1983).

4.2 Differences in Perceived Restorativeness and Fascination among Clusters

The results from the mixed-effects model on total perceived restorativeness (PR) provide support for our hypothesis that the structural visual composition of natural environments, as captured by basic visual features (BVFs), plays a significant role in shaping restorative appraisals. Looking at the clusters that emerged using images as units of grouping (Cluster Analysis 2), the finding that the Texture cluster (Cluster 3), characterized by a high texture gradient but low or absent levels of other structural cues, was consistently rated as the least restorative confirms our expectation that visual richness alone does not elicit a strong restorative potential. In contrast, the Complexity (Cluster 2), Expansion (Cluster 1), and Openness (Cluster 3) clusters, each defined by distinct patterns of structured visual elements (BVFs), elicited significantly higher PR scores, suggesting that compositional organization and spatial layout provide critical perceptual cues in restorative evaluations. Other authors had already identified the importance of the spatial layout that defines a certain type of scene in connection with PR. Ulrich (1983) had linked the perception of restorativeness to certain structural attributes of the environment, such as complexity, structural coherence, and depth cues. Also, Hunter and Askarinejad (2015), between the structural attributes of a scene that determine a sense of restorativeness and aesthetic pleasantness include: openness, complexity, depth, and structural forms (i.e., the fact that the image appears as a coherent and harmonious gestalt whole). Complexity, defined as variety and richness in the physical structure and content of a scene, was identified as a predictor of restorativeness by Ewing et al. (2006) and Schirpke et al. (2013). Scenes with high openness (i.e., scenes with wide and spacious vistas in comparison to scenes with restricted views) have been linked to high levels of perceived restorativeness by Ewing et al. (2006) and Tveit et al. (2006). Depth cues that generate BGPs expansion (i.e., perception of being able to go deep into the scene space to explore it) were also considered predictors of restorativeness by authors such as Ulrich (1983) and Kaplan et al. (1975).

Regarding the BGPs that emerged from cluster analyses, the fact that complexity and openness differed significantly in their perceived restorativeness further supports the idea that not all structural richness is equally effective in supporting recovery-oriented responses. The Openness cluster (Cluster 4), with its elevated visibility and height of the horizon line and aerial perspective, was rated as more restorative than the Complexity cluster (Cluster 2), which featured more varied but less coherent spatial arrangements. This result aligns with existing theories emphasizing the restorative value of vast, legible environments that facilitate psychological distance and attentional soft fascination (Orians & Heerwagen, 1992; Kaplan & Kaplan, 1982).

Overall, these findings extend previous literature on perceived restorativeness by demonstrating that specific configurations of early visual features contribute to the aesthetic and psychological impact of natural scenes (Hunter and Askarinejad, 2015). They also underline the importance of going beyond global affective responses to account for the microstructure of perceptual input when assessing environmental quality and its restorative potential.

The findings related to the fascination dimension of perceived restorativeness provide important insight into how specific visual characteristics influence restorative potential. In line with our expectations and theoretical accounts of fascination as a core mechanism in restorative experiences (Kaplan, 1995; Herzog et al., 2003), images clustered as Complexity (Cluster 2), Expansion (Cluster 1), and Openness (Cluster 4) all elicited significantly higher fascination ratings than those in the only Gradient Textur cluster (Cluster 3). This suggests that environments rich in spatial organization, depth cues, or visual amplitude are more likely to capture attention effortlessly and elicit aesthetic appreciation, key components of fascination.

Notably, the Complexity cluster yielded the highest fascination scores, significantly surpassing even the Openness cluster, despite the latter's association with vastness and horizon visibility. This result highlights the relevance of visual richness and structural variation in eliciting immersive engagement. Interestingly, no significant difference emerged between the Complexity and Expansion clusters, suggesting that both intricate detail and directional spatial depth may similarly contribute to the feeling of being drawn into the scene.

Conversely, the Texture cluster, represented by a single image high in surface granularity but low in other structuring properties, was perceived as markedly less fascinating. This reinforces the idea that mere visual stimulation, in the absence of higher-order compositional or spatial features, may be insufficient to evoke fascination. Altogether, these results support the centrality of visual structure, spatial layout, and compositional richness in shaping restorative responses, particularly in terms of attention engagement and wonder.

4.3. Final Observations and Future Perspectives

This study contributes to shedding light on the relationship between the features that define the structural layout of an environment (BGPs) and the perception of restorativeness (PR). It combines the main theories explaining environmental restorativeness (ART, Kaplan, 1995; SRT, Ulrich, 1983, 1991) with Gestalt and psychophysical studies, identifying the elementary features of an image (BVFs) playing a fundamental role in the perceptual response of subjects. Previous authors (Hunter & Askarinejad, 2015; Oliva & Torralba, 2001;) have hypothesized that the structural layout of an image (i.e., level of openness, expansion, depth, and complexity) had a role in eliciting PR but a precise connection between the BGPs defining the structural layout of an image and the basic visual features capable of giving rise to the perception of the overall layout itself had never been established. The results of this study, having as theoretical basis the Gestalt principles of perception and the roles of two-dimensional drawing - i.e., the "clues" that painters use to represent on a two-dimensional space a three-dimensional scene - showed that some basic elements of the scene combine together to generate the perception of the BGPs of an image. Precisely three BGPs emerged from the aggregation of some BVFs:

- Openness: given by the conjunction of horizon line height, horizon line visibility, and aerial perspective;
- Expansion: given by the combination of linear perspective, chiaroscuro, and collinearity;
- Complexity: given by the symmetry dimension.

Regarding the relationship between the BGPs of an image and the perception of restorativeness, results confirmed our supporting hypothesis that BGPs play an influential role in generating PR. In line with the Scene Centered Approach (Oliva and Torralba, 2001), BGPs allow the subject who faces a new environment to create an approximate but rapid representation of how the environment is structured. This contributes to defining what he or she can or cannot do within the environment. In line with the main theories of restorativeness (Biophilia Hypothesis, Wilson, 1984; SRT; Ulrich, 1983, 1991; ART; Kaplan & Kaplan, 1989; Kaplan, 1995), subjects perceive restorative environments suggesting the possibility of exploration, without feeling of danger, rich in their structure and content, elicit curiosity, aesthetic pleasantness, and suggesting the presence of exploitable resources - i.e., environments with structural features suggesting openness, expansion, and complexity. The study clearly showed that the clusters of images characterized by the presence of one of these structural features generated statistically significantly greater perceptions of restorativeness in experimental subjects, than the cluster with only marked texture (i.e., visual stimulus rich in detail but not sufficient to generate a regenerative experience).

The study also suggests that different BGPs may play distinct roles in eliciting the sub-dimensions that make up PR. In fact, for overall PR, the BGP Openness (i.e., spacious scenes with wide views) resulted the most relevant, followed by Complexity (i.e., richness and harmony of elements) and Expansion (i.e., great perception of distance and depth). For Fascination - the main component of PR, according to Attention Restoration Theory (Kaplan & Kaplan, 1989; Kaplan, 1995) - the situation is reversed, with Complexity playing the most important role in eliciting fascination, followed by Openness and Expansion. The role each BGP plays in determining the different sub-dimensions of PR may be the subject of subsequent in-depth studies.

Given the encouraging results, future research prospects open up on several fronts. First, it will be crucial to extend the investigation to more images and types of environments, including urban or hybrid environments, to test the generalizability of the proposed model. In fact, while it is true that structural layouts suggesting openness, expansion, and complexity are more marked in natural environments (Oliva and Torralba, 2001), it is also possible that urban or hybrid environments are designed in such a way as to emphasize the BGPs associated with the perception of restorativeness. Furthermore, to this type of experimental design, considering only the perceptual responses of the subjects, other types of measurements, such as physiological or neuropsychological measures (e.g., eye-tracking, electrodermal activity, EEG), could be integrated to test the impact of BGPs and BVFs on attentional and affective mechanisms. This would allow for stronger connections to be found with the main theories related to restorativeness, namely Attention Restoration Theory (Kaplan & Kaplan, 1989; Kaplan, 1995), which focuses on the attentional processes of “soft fascination” elicited by physical environmental features, and Stress Recovery Thoery (Ulrich, 1983, 1991), which instead emphasizes the affective response that environments with given features elicit. Finally, it would be interesting to explore the role of individual variables, such as environmental preferences, the need for restoration, or cultural differences, in modulating the perception of the restorative qualities of environments. Although the literature that has investigated the relationship between individual variables and PR has not yielded great results, suggesting that the mechanisms that lead to the perception of restorativeness are fairly universal and more related to environmental peculiar characteristics than to individual characteristics, it cannot be ruled out that an early exposure to certain types of places (i.e., having lived in marine vs. mountain environments) or specific personological traits, as well as the more or less pronounced need for restortion, do not play a role in PR.

4.3. Limitation of the Research

Despite the theoretical contributions and empirical insights offered by this study, several limitations should be acknowledged. First, the measurement of perceived restorativeness (PR) relied exclusively on a self-report instrument (PRS-11, Pasini et al., 2014), without the inclusion of physiological or behavioral indicators. Although the use of validated psychometric tools enables the efficient assessment of the subjective experience of restorativeness, future studies could benefit from the integration of complementary measures, such as heart rate variability, electrodermal activity, or eye-tracking data, to capture the attentional, emotional, and stress-recovery responses related to the restorative experience in a more comprehensive and multimodal manner.

Second, the limited number of stimuli (12 images) may have constrained the variability of visual features and weakened the generalizability of the findings. While the selection was carefully curated to represent a range of structural configurations, a broader and more diverse stimulus set would allow for a more robust test of the hypothesized relationships. Third, all the images depicted natural landscapes, with no inclusion of urban or built environments. This limits the applicability of the results to real-world settings, particularly those in which restorative experiences may occur outside of purely natural contexts (e.g., architecturally rich public spaces, green urban areas). The inclusion of urban scenes in future studies would allow for a more nuanced investigation of how the visual-structural layout of a scene contributes to restorativeness across different environmental typologies.

Another important limitation relates to the structure of the image clusters that emerged from our analyses. The Texture cluster (Cluster 3 in cluster analysis nr. 2), which consistently received the lowest ratings in both PR and fascination, was composed of a single image. As such, the interpretation of this cluster should be approached with caution, since its unique characteristics may not adequately represent the broader perceptual category of texture-based configurations. Moreover, although clustering procedures were theory-driven and aligned with the Scene-Centered Approach, the restricted number of items per cluster may have introduced noise or exaggerated inter-group differences.

Finally, the sample composition, predominantly female and composed of psychology students, may have introduced unmeasured individual differences related to environmental preferences, aesthetic sensitivity, or need for restoration. Future research should aim to replicate the findings in more heterogeneous samples and incorporate person-level variables that may modulate the perception of environmental restorativeness.

4.4. Practical Implications of the Results

The findings of this study provide meaningful insights with practical relevance for the design and evaluation of restorative environments. One of the most significant contributions lies in having shed light on the perceptual mechanisms connecting basic image features (BVFs), visuo-structural layouts (BGPs), and the experience of restorativeness. By moving beyond the binary distinction between "natural-restorative" and "built-not restorative" settings, the study highlights how specific compositional features - such as openness, expansion, complexity, and visual coherence - can elicit restorative responses regardless of the scene's ontological category. This has important implications for applied fields such as architecture, urban planning, and environmental design. Once the visual-structural characteristics that enhance perceived restorativeness are clearly identified, they can be intentionally incorporated into the design of human-made environments - such as urban parks, public gathering spaces, therapeutic settings, offices, and residential interiors - with the aim of fostering cognitive recovery and psychological well-being.

Furthermore, these results support the development of visual assessment tools that can be used by designers and planners to evaluate the restorative potential of environments at the early stages of a project, even before physical construction. This perceptual-based approach also opens new opportunities for the use of virtual simulations and visualizations to test and refine design solutions in immersive and cost-effective ways. Additionally, the study offers useful insights for disciplines such as environmental psychology, landscape architecture, and workplace wellness, encouraging interdisciplinary collaboration aimed at creating spaces that are not only functional and aesthetically pleasing but also psychologically beneficial.

By demonstrating that restorative potential can emerge from a structured interplay of basic visual elements, this research supports the idea that environments - whether natural or built - can be shaped to promote attention restoration, emotional and stress relief through perceptually informed design.

Appendix

Supplementary Table 1. PRS-11 Scale and the Dimensions Underlying the Scale

Nr	Item	Dimension
1	Places like that are fascinating	Fascination
2	In places like this my attention is drawn to many interesting things	Fascination
3	In places like this it is hard to be bored	Fascination
4	Places like that are a refuge from nuisances	Being away
5	To get away from things that usually demand my attention I like to go to places like this	Being away
6	To stop thinking about the things that I must get done I like to go to places like this	Being away
7	There is a clear order in the physical arrangement of places like this	Coherence
8	In places like this it is easy to see how things are organized	Coherence
9	In places like this everything seems to have its proper place	Coherence
10	That place is large enough to allow exploration in many directions	Scope
11	In places like that there are few boundaries to limit my possibility for moving about	Scope

Appendix A

The 12 natural images used in the Study.

Image 1

Image 2

Image 3

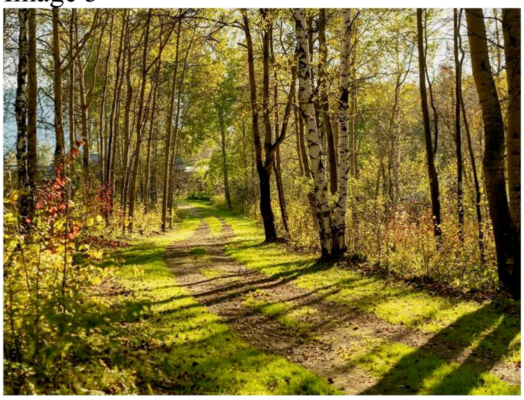


Image 4

Image 5

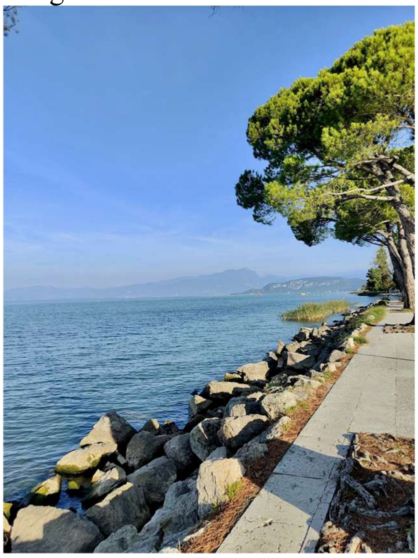


Image 6

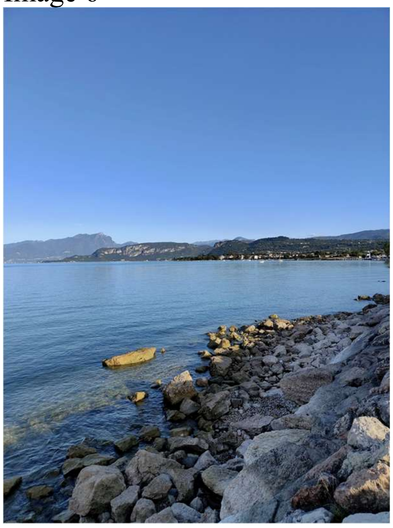


Image 7

Image 8

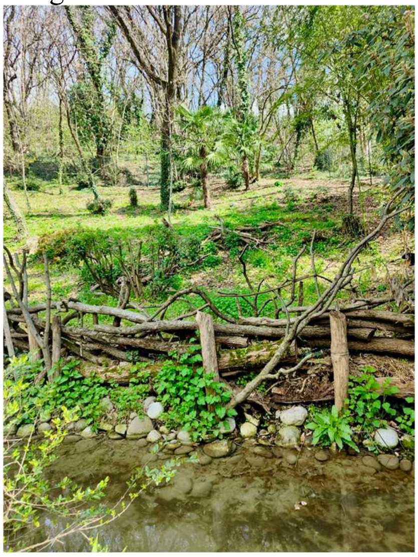


Image 9

Image 10

Image 11

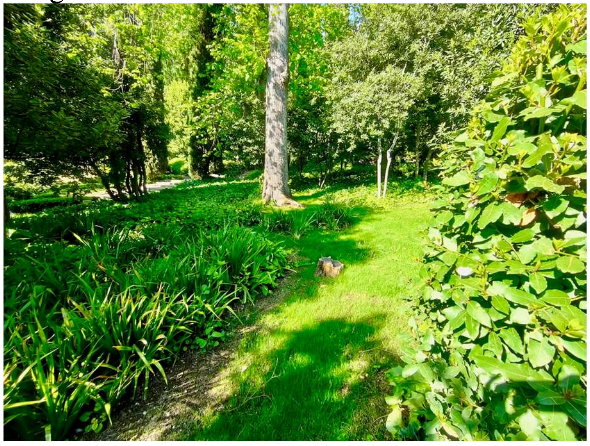


Image 12

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CONCLUSIONS

Concluding Considerations Regarding the Main Findings of the Research

This work aimed to “deconstruct” the concept of restorativeness as applied to physical environments. Starting from a phenomenological perspective (Biassoni et al., 2023), restorativeness was conceptualised here as a “tertiary quality” (Bozzi, 1989; 1999) of the environment, i.e., a quality resulting from the match between the physical properties of the environment and the subject's perceptual system. We have focused on understanding how an environment must be physically structured to produce a sense of restorativeness (i.e., a sense of cognitive and emotional relief; Ulrich, 1983) in the subjects who inhabit it. To answer this question, as a preliminary step, it was helpful to understand how psychological theories describe the functioning of the human visual perceptual system.

The Gestalt school (Kanizsa, 1980; Wertheimer, 1985; Wagemans et al., 2012) was the first to state and demonstrate that the image we have of an environment is “constructed” by aggregating basic items that immediately attract visual attention. The human visual system, when confronted with a stimulating visual configuration - i.e., a series of elementary items that can be connected in different ways - relies on ratios and relationships between basic items (e.g., similarity, contrast, symmetry, collinearity, good continuation) to define the layout of the image (e.g., grouping, contour creation, figure/background articulation, modal and amodal completion). In this way, it is possible to move from a set of physical stimuli to an image that has meaning for the observing subject. The work of Kimchi and collaborators (Kimchi, Yeshurun & Cohen-Savransky, 2007; Kimchi, Yeshurun, Spehar & Pirkner, 2016; Kimchi & Peterson, 2008), founded on gestalt theories, has shown, using psychophysical paradigms based on correctness and speed of responses, that if, in a stimulating visual configuration, the items are arranged in conformity with the gestalt rules favouring perception, the subject's visual attention is automatically attracted to the gestalt relations between items and the articulation figure-background occurs more quickly and with less effort.

The Feature Integration Theory (FIT; Treisman & Gelade, 1980) is a gestalt-inspired theory that clarified the role and functioning of visual attention in originating images of the environments in which subjects are located. At an early stage of vision, the visual system cannot simultaneously process all the stimuli from the physical world by which it is bombarded, so visual attention is automatically attracted to certain basic features of the stimuli (e.g., similarity, contrasts, orientation in space) in order to create an approximate but rapid representation of the environment (e.g., object outlines, spatial layout). This facilitates the subsequent processes of focusing voluntary attention on parts of the environment of interest to the observer. Many psychophysical studies have demonstrated the importance of certain salient features of physical items in attracting automatic visual attention through bottom-up processes in early stages of vision (Wolfe & Cave, 1999; Pramod & Arun, 2014; Jingling, Tseng & Zhaoping, 2013; Jingling & Zhaoping, 2006, for a systematic review see Kamkar, Moghaddam, & Lashgari, 2018)

A more recent theory called Scene Centered Approach (SCA; Oliva & Torralba, 2001; 2002; Green & Oliva, 2009) can be considered an evolution of the FIT. It is specific in explaining the role of certain global physical properties of the environment (BGPs) in viewing and understanding it. According to the SCA, to form an initial representation of the environment in which the subject is located, he or she relies on certain structural (i.e., openness, expansion, and depth) and functional environmental characteristics (i.e., transience, concealment, temperature). This informations, in turn, are derived from the (gestalt) aggregation of certain basic visual items (BVFs) not fully defined by the authors. Functional and structural BGPs provide the subject with important information on what resources or threats may be contained into the environment and, ultimately, what it is good to do or avoid doing within it.

In this study, SCA was connected with the main theories of environmental psychology explaining the construct of restorativeness (i.e., Attention Restoration Theory; ART, Kaplan & Kaplan, 1982; Kaplan, 1995; Stress Recovery Theroy; SRT, Ulrich, 1983). According to ART and SRT, the sense of restorativeness is elicited by the presence of certain global features of the environment suggesting richness of resources and absence of threats. Restorativeness is conceptualized as an automatic, fast, and pre-cognitive response to certain global features of the environment, facilitating a sense of well-being. In particular, ART identifies soft fascination, i.e., a kind of automatic but non-coercive attraction of human attention by specific structural configurations of the environment or by salient features present in it, as the main sub-dimension of the restorativeness construct. For this reason, in the first experimental work of this study (see Chapter 2) it was hypothesized that the BGPs identified by the SCA play a role in explaining the perception of restorativeness. Results of the study confirmed the hypothesis. In fact, BGPs that act as “clues” regarding the spatial layout of the environment (i.e., openness, expansion, and depth) were shown to play a role in explaining the perception of restorativeness, with environments with high openness (i.e., wide, open vistas, not obstructed by foreground visual elements), expansion (i.e., environments with a spatial layout with a marked linear perspective, i.e., with a central vanishing point attracting the gaze) and depth (i.e., environments providing a high sense of depth, with great contrast in size between the figure in the foreground and the figure in the background) reporting a statistically significant higher level of restorativeness, compared to environments in which these three BGPs were less evident. Interestingly, an interaction effect was also found between the three structural BGPs in eliciting restorativeness. Since these structural features are embedded in the scene, thus difficult to isolate and separate (e.g., a high openness environment generally also has medium to high levels of depth, as does a high expansion environment), it was seen that the simultaneous presence of the three BGPs increases the level of perceived restorativeness. The study thus demonstrated that elements providing clues about the structural layout of the environment play a role in generating the four fundamental sub-dimensions of perceived restorativeness as identified by ART, namely, soft fascination (i.e., the capture of the attention), being away (i.e., the sense of being able to range imaginatively in the environment), coherence (i.e., the harmony and order in the environmental structure) and scope (i.e., the possibility of moving and exploring the space). Based on these results, the dimensionality of restorativeness can be conceptualized as higher-order perceptual characteristics that derive, at least in part, from perceptual clues about the structural organization of the physical space in which the subject is located.

These results also allow for a better interpretation of the numerous findings in literature according to which natural environments are more restorative than urban and built environments (for a literature review see Berto, 2014 and for a meta-analysis see Menardo, Brondino, Hall & Pasini, 2021). We can hypothesize it is not the mere presence of natural elements per se (e.g., the presence of plants, water, etc.) but also the physical layout of the space in which these elements are located (e.g., openness, expansion, depth) that favors the sense of restorativeness. In our study, the images used all depicted natural scenes, but these were structured in such a way as to have higher or lower levels in the investigated BGPs. The fact is that, generally, natural scenes, compared to scenes of urban or built places, have a spatial layout with higher levels of openness, expansion and depth. Being able to design built environments with good levels in the BGPs openness, expansion, and depth could increase the level of perceived restorativeness of the latter.

Once it was verified that, in a scene, a marked presence of structural BGPs - i.e., openness, expansion, and depth - increases perceived restorativeness, we moved on to investigate which are the smallest, basic portions of the stimulating visual configuration - i.e., the basic visual features (BVFs) - capable of conferring ample openness, expansion, and depth to scenes. In fact, in the SCA, the authors provided only an overall description of the structural and functional properties of an image, without analyzing the BVFs that compose it in detail. Since this study analyzes the perception of restorativeness from a Gestalt perspective, it was deemed appropriate to investigate BVFs. For this investigation, described in the second experimental study (see Chapter 3), reference was made to Pictorial Indicators of Three-Dimensional Space (PITS), i.e., the "tricks" that painters and draftsmen use to represent three-dimensional space on a two-dimensional sheet (the drawing sheet). PITS allow the stimulating visual configuration to be broken down into basic items (e.g., lines, contours, edges, and single colors) and the relationships between these items to be analyzed. Eight PITS have been identified, namely: visibility of the horizon line, height of the horizon line, linear perspective, aerial perspective, texture gradient, chiaroscuro, symmetry, and collinearity. It is hypothesized that these PITS, when combined, contribute to forming the structural BGPs of the scene. Concerning BGPs, in addition to openness, expansion, and depth, a fourth global property of the image has been included, namely complexity. In conformity with the literature on the topic (Roberts, Schira, Spehar & Isherwood, 2022; Lavdas & Schirpke, 2020; Viengkham, Isherwood & Spehar, 2022), complexity also contributes to the creation of a fast representation of the image and is connected to perceived restorativeness, in the sense that images with average levels of complexity and order elicit restorativeness.

The results obtained from study two confirmed our hypothesis. The two cluster analyses conducted using images and basic visual features as factors for aggregation showed that images tend to aggregate by BVFs, generating groupings that can be described by their BGPs. Specifically, four clusters emerged, named: a) Openness (composed of the BVFs horizon line height, horizon line visibility, and aerial perspective), b) Expansion (composed of the BVFs linear perspective, chiaroscuro, and collinearity), c) Complexity (composed of the BVF symmetry), d) Lack of BGPs (cluster represented by an image with a poor structural layout in all the analyzed BVFs, except for texture gradient).

The subsequent analyses, conducted using mixed linear models, showed that these clusters differed statistically significantly in terms of overall perceived restorativeness (PR) and fascination (FAS) levels - the main component of restorativeness, according to ART. Specifically, the Lack of BGPs Cluster showed the lowest levels of PR and FAS, compared to all other clusters. With regard to overall PR, the Openness Cluster had the highest scores, followed by the Complexity and Expansion clusters. Concerning the FAS dimension, the Complexity Cluster had the highest scores, which differed statistically significantly from the Complexity (with the second highest score) and Expansion (with the third highest score) clusters.

These results, although preliminary and based on a limited number of images, add a missing piece to our understanding of the construct of perceived restorativeness. Not only do they demonstrate that spaces with different structural layouts (i.e., spaces that differ in the marked presence of distinct BGPs) produce different levels of PR, but they have also helped to identify which specific BVFs contribute to the creation of images with distinct BGPs.

Theoretical and Practical Implications of the Research

The two experimental studies described in this work are believed to have theoretical and practical implications. From a theoretical point of view, they have succeeded in connecting Gestalt-derived theories of visual perception to the main theories explaining the sense of restorativeness that is generated through contact with certain physical environments (ART, Kaplan & Kaplan, 1982; Kaplan, 1995; SRT, Ulrich, 1983), showing that nature itself is not the only factor capable of generating restorativeness, but that the spatial layout of the environment in which the subject is located also matters. This is in line with the evidence put forward by some authors (Carrus et al., 2014; San Juan, Subiza-Pérez & Vozmediano, 2017; Scopelliti, Carrus, Bonaiuto, 2019; Straga et al., 2023), according to whom even man-made environments are capable of eliciting restorativeness as long as they respect certain spatial layouts.

The present findings have relevant practical applications in environmental design, urban planning, and landscape architecture. Demonstrating that the structural layout of an environment - specifically the presence of high openness, expansion, and complexity - significantly contributes to perceived restorativeness suggests that restorative potential can be actively enhanced through deliberate spatial design. This means that the capacity of an environment to promote cognitive and emotional recovery is not exclusively tied to the presence of natural elements, but also to how these elements, as well as built features, are spatially arranged.

Designers and planners can leverage these insights to create both natural and built environments that facilitate restoration. For example, in urban contexts, even spaces with limited vegetation could elicit restorative responses if they incorporate design strategies that increase visual openness (e.g., avoiding unnecessary obstructions to distant views), expansion (e.g., using linear perspective cues such as aligned pathways or architectural features converging toward a focal point), and complexity (e.g., enriching the space with symmetrical elements and embellishing it with harmonious details). Such configurations may naturally attract attention, evoke a sense of "fascination", "being away," and provide perceptual coherence, thereby enhancing well-being.

These principles can be applied across a wide range of settings: public parks, pedestrian areas, hospital gardens, school courtyards, and workplace interiors. Integrating structural cues that the visual system processes automatically in early stages of perception may be particularly beneficial in high-stress environments - like some types of work environments - where quick and effortless access to restorative experiences is crucial.

Moreover, the identification of specific basic visual features (BVFs) - such as horizon line position, aerial and linear perspective, chiaroscuro, symmetry, and collinearity - as building blocks of the key structural properties provides concrete guidelines for architects, landscape designers, and visual artists. By intentionally embedding these perceptual cues in spatial layouts, it becomes possible to enhance restorativeness not only in real-world spaces but also in virtual environments, simulations, and therapeutic visual media.

In this way, the study supports a paradigm shift: from simply adding "green" or "natural" elements, to designing environments - whether natural, built, or hybrid - that follow perceptual and structural principles proven to foster restoration and human well-being.

Beyond their theoretical contributions, the methods employed in this study for assessing basic visual features (BVFs) and basic global properties (BGPs) have potential for practical application in architectural and urban design processes. The rank-order method and the pairwise comparison method used to evaluate BVFs and BGPs respectively - where participants compare and rank a set of images according to the intensity of specific visual features - proved effective in capturing subtle perceptual differences between complex stimuli in a way that reduces common biases found in traditional rating scales (e.g., simple Likert scale). This approach could be profitably adapted to participatory design settings, such as the evaluation of architectural renderings, urban landscape proposals, or virtual reality simulations. By presenting multiple design alternatives simultaneously and asking stakeholders or end users to rank them according to perceived spatial openness, depth, or other restorative structural cues, designers could obtain direct, comparative feedback to guide spatial composition.

Integrating these measurement tools into architectural and urban planning workflows could bridge the gap between perceptual science and spatial design. Involving potential users in the evaluation of visual configurations before construction - whether through physical models, photorealistic renderings, or immersive VR environments - would enable designers to select layouts that maximize restorative potential based on empirical, user-driven data. Such an approach could enhance the human-centered quality of design projects, ensuring that built environments not only meet functional requirements but also actively support psychological well-being.

Limitations and Future Directions of the Research

Although the present research provides novel contributions to understanding the perceptual basis of perceived restorativeness (PR), several limitations need to be acknowledged, each of which opens potential avenues for future investigation. First, the research was conceived as an exploratory study and was conducted on a relatively small and homogeneous set of stimuli, consisting of only twelve images, all depicting natural environments in Central Europe. While this approach allowed for precise control over the visual variables under investigation, the restricted variety of scenes inevitably limits the generalizability of the results. Expanding the image set to include a wider range of environments - both natural and built, as well as hybrid landscapes and culturally diverse settings - would allow future research to test the robustness of the relationships observed here.

A second limitation concerns the scope of the restorative factors considered. The present work focused deliberately on structural layout properties of scenes - the basic global properties (BGPs) - and on their underlying basic visual features (BVFs), as elicitors of perceived restorativeness (PR). However, the restorative potential of an environment depends on a broader set of factors, many of which have been documented in the literature. Among these, the presence of vegetation and natural materials plays a central role, as highlighted in the principles of biophilic design (Hung & Chang, 2021; Kellert, 2008; Richardson & Butteler, 2022), which emphasize the human predisposition to respond positively to natural forms, textures, and fractal patterns.

Similarly, environments that incorporate water features - so-called "blue spaces" - have been found to exert powerful restorative and stress-reducing effects, likely due to multi-sensory stimulation and deep-rooted evolutionary associations with resource abundance (White et al., 2010; Völker & Kistemann, 2011). Future studies could integrate these elements with structural cues to examine whether they act additively or interactively in eliciting PR, and to what extent their effects may depend on their spatial arrangement within a scene.

A further limitation arises from the phenomenological stance (Bozzi & Longo, 1998; Bozzi, 1999) adopted in the study, which conceptualized PR as a "tertiary quality", emerging from the encounter between the physical configuration of a scene and the perceptual system of the subject, without explicitly modelling the characteristics of the perceiver. Yet, it is plausible that individual differences substantially modulate the perception of BVFs and BGPs and, consequently, the restorative response. For example, personal experiences may bias perception: an individual with positive childhood memories of open rural landscapes might find similar settings particularly restorative, whereas another person without such associations may not. The momentary psychological state is also relevant: individuals with a heightened need for restoration - for instance, due to high stress or mental fatigue - may be more sensitive to environments high in openness, expansion, and depth, responding to them more strongly than those in a neutral state. In addition, stable personality traits such as openness to experience, sensation-seeking, or neuroticism could influence whether structural cues are interpreted as inviting, overwhelming, or neutral. Including these person-related factors in future research could yield a richer understanding of how physical layout and individual predispositions jointly shape PR.

Methodologically, the present work relied on static, two-dimensional photographs, which, although useful for isolating specific visual properties, cannot replicate the dynamic, multi-sensory nature of real-world environments. In reality, the perception of space involves not only visual cues but also auditory, tactile, and proprioceptive information, as well as changes in perspective generated by movement. Immersive technologies such as virtual reality (VR) or augmented reality (AR) could be used in future studies to present participants with more ecologically valid simulations, enabling the investigation of PR in contexts that more closely resemble lived experience.

Finally, this study approached PR as an almost immediate, pre-cognitive response to structural cues. While this perspective is consistent with the theoretical framework adopted, it leaves open the question of how restorative experiences evolve over time as individuals explore and interact with an environment. Longitudinal or time-course studies could reveal whether BGPs and BVFs contribute not only to the initial "soft fascination" described by the Attention Restoration Theory, but also to the maintenance or deepening of restoration during prolonged exposure. Given the way this research was structured, it cannot be ruled out that the "novelty" effect caused by the presentation of the images contributed to increasing soft fascination (i.e., rapid and automatic attraction of attention) and the resulting PR. It will be necessary to verify the durability of this restorative effect in the future.

In conclusion, while the present work advances a perceptual-structural account of PR, future research would benefit from adopting more complex, multi-factorial models that combine structural layout cues with biophilic elements, account for individual differences, and capture the dynamic, multi-sensory qualities of environments. Such an integrative approach would provide a more comprehensive understanding of how to design spaces - natural, built, and hybrid - that consistently foster restoration and human well-being.

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