MSc Brain and Cognitive Sciences
Literature Thesis

Why do we find Nature beautiful? A critical literature review on the link between Nature, Aesthetic preference, and Restoration

By

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Abstract:

Physiological, affective, and cognitive benefits of exposure to real and simulated nature have been demonstrated thoroughly over the past 40 years. Many theories including the biophilia hypothesis rely on evolutionary assumptions to justify a universal preference for natural over built environments. Furthermore, research has established a link between aesthetic preference for an environment and its restorative potential. In this literature thesis, nature is first defined within the scope of environmental psychology, with particular interest to caveats in its operationalization. The link between aesthetics and restoration is explored through bottom-up stimulus features and top-down semantics. Various theories within the field of research are discussed with regards to explaining what may drive our aesthetic preference for nature. Overall, the role of top-down meaning associations seems overlooked compared to genetic and epigenetic factors. There is a need for better understanding why individuals relate nature to positive feelings, beauty, and ultimately, restoration, which should rely less on evolutionary theory and give more weight to interindividual differences in associated meaning.

"In every walk with nature, one receives far more than he seeks." – John Muir

Our relationships with urban and natural environments are contrasted in terms of functional, psychological, as well as aesthetic appeal. We have a practical relationship with urban environments, where habitat, industries, and services are concentrated. On the other hand, we incorporate nature into our urban environments in the form of parks, gardens, and flowerbeds on our balconies, for leisure, relaxation, decoration, and restoration purposes. Nature represents a source of inspiration for artists and meditators alike, we ornament our interiors with house plants, and we select landscapes from our most beautiful travels as wallpapers for our cell-phones. These all stem from the broad idea that nature is 'naturally' appealing to many – if not most of us. But why? This literature review will first define of what nature consists, and how it is operationalized in environmental psychology research. Then, it will examine aesthetic preference, its neural correlates, and the link with restorative potential. Finally, various theories attempting to explain our preference for natural environments shall be investigated.

In the field of environmental psychology, there is increasing evidence pointing towards beneficial health effects of exposure to nature. These include, though are not limited to, reduction of stress (Berto, 2014; Chang and Chen, 2005; Lohr et al., 1996; Ulrich et al., 1991; Valtchanov et al., 2010), restoration of attentional capacity (Berto, 2005; Stevens, 2014), improvement of mood and mental health (Alcock et al., 2014; Mantler and Logan, 2015; van den Berg et al., 2003; White et al., 2013), well-being and happiness (Berman et al., 2008, 2012; MacKerron and Mourato, 2013; Nisbet and Zelenski, 2011; White et al., 2013), positive affect (Berman et al., 2012; Bratman et al., 2015; Mayer et al., 2009; Valtchanov et al., 2010), memory, working-memory and attention (Berman et al., 2008, 2012; Bratman et al., 2015a; Lee et al., 2015; Taylor and Kuo, 2009), creativity (van Rompay and Jol, 2016), increase of physical activity (Bedimo-Rung et al., 2005; Humpel et al., 2002), decreased aggression and crime (Kuo and Sullivan, 2001), and decreased depressive rumination (Bratman et al., 2015a, 2015b). Research has also suggested that the importance of feeling connected to nature for our well-being could even be likened to established factors such as income and education (Capaldi et al., 2014).

One hypothesis for explaining such beneficial effects of exposure to nature has been termed the biophilia hypothesis. Broadly, biophilia refers to "the urge to affiliate with other forms of life" (Kellert and Wilson, 1993), which characterizes humans with an innate tendency to respond positively to nature (Ulrich, 1993). Furthermore, the positive responsiveness would entail a "genetic basis". It is hypothesized that ancestral humans underwent their most important evolutionary changes during the Pleistocene era (2600ka – 12ka), since the Homo genus appeared around 2.2 million years ago

(Gifford, 2007). In contrast, cities emerged only well into the Holocene era, around 4500 B.C at the earliest (Crawford, 2004). Thus, it seems plausible that the natural environments in which we evolved could have shaped many aspects of modern brain functioning (O'Connell, 2013). Urbanization has grown at such a pace that today, more than 55% of the global population lives in an urban environment (United Nations, 2018). In addition, people are spending the vast majority of their time indoors: up to 90% in the USA between 1992 and 1994 (Klepeis et al., 2001), and up to 85% in the UK in 2013 (MacKerron and Mourato, 2013). Our interactions with nature have dramatically decreased as urbanization has taken over modern society (Soga et al., 2020; Turner et al., 2004), replacing groves, hills, rocks, and rivers with offices, supermarkets, cars, and computers. At its core, the biophilia hypothesis posits that behavioral, affective, and cognitive components formed in natural landscapes during our evolution (still) exert influence in modern day humans, thus creating a mismatch between the environment in which we evolved and the one in which we currently live (Barkow et al., 1992; Buss, 2000; Gifford, 2007; Kellert and Calabrese, 2015). This evolutionary adaptation from nature can be evidenced in the fact that we still react strongly to aversive natural stimuli, such as snakes and spiders – sometimes as strong or even stronger than to aversive stimuli salient in our modern lives, such as guns. (Gifford, 2007; Ulrich, 1993). Crucially, however, biophilia is not only genetic. It can also be shaped by culture and life experiences (Kellert, 2003, 2012; Orr, 1993), particularly during childhood (Soga et al., 2020; Thompson et al., 2008). In the United Kingdom, the frequency of visits to woodlands and green spaces during childhood was found to strongly predict such a behavior in adulthood (Thompson et al., 2008).

Biophilia has paved the way for theories attempting to explain mechanisms governing the relationship between humans and nature. Stress Reduction Theory (SRT; Ulrich et al., 1991) posits that interactions with non-threatening nature may have beneficial effects on physiological indicators of stress (e.g. heart rate, muscle tension) as well as affective and cognitive components. Throughout evolution, individuals who exhibited a *restorative* response to unthreatening natural contents would have benefitted from attenuating their stress responses and restoring their physical energy following a threatening encounter. Thus, it contends that modern humans may have a biologically prepared readiness to acquire restorative responses to unthreatening natural settings, but not to most urban or built settings. In this framework, rapid and unconscious processes mediate initial affective responses (like/dislike) which in turn may determine subsequent cognitive, affective, and behavioral responses (Hietanen and Korpela, 2004; Korpela et al., 2002; Ulrich et al., 1991). However, a lack of clear empirical evidence for the theory's evolutionary assumptions have led researchers to put them into question (Joye and van den Berg, 2011).

Attention Restoration Theory (ART; Kaplan and Kaplan, 1989) stems from the idea that directed (top-down) attention is a limited resource, which is susceptible to depletion and may lead to fatigue. This leads to diminished cognitive performance and executive control (Kaplan, 1995; Kaplan and Berman, 2010). Urban environments are thought to be less restorative overall than natural environments because they demand more attention and foster higher cognitive load (Grassini et al., 2019; Kaplan and Berman, 2010; Valtchanov and Ellard, 2015; van den Berg et al., 2007). ART maintains that restoration in the context of mental fatigue is encouraged by four factors: "being away" from one's usual thoughts and concerns, the "extent" of the environment, which refers to the ability of an environment to make one feel immersed and engaged, "compatibility", which entails a sense of intrinsic motivation, personal preference, and familiarity with regards to the environment, and "soft fascination", or the propensity of an environment to hold one's attention without requiring focus or directed attention. (Kaplan, 1995, 2001; Staats, 2012). Although many relaxing settings or activities may elicit restoration – places of worship (Herzog et al., 2010), museums (Kaplan et al., 1993), meditation (Kaplan, 2001; Lymeus et al., 2018) – nature is of particular importance as it has an "aesthetic advantage" with regards to these four factors (Kaplan and Kaplan, 1989). Many researchers have established the restorative effects of exposure to nature on attention, be it through visual exposure (Berman et al., 2008; Berto, 2005; Ibarra et al., 2017; Lee et al., 2015; Stevens, 2014; Tennessen and Cimprich, 1995; van den Berg et al., 2003), physical exposure (Berman et al., 2008; Bratman et al., 2015a, 2015b; Hartig et al., 2003; McMahan and Estes, 2015), or sound (Ratcliffe et al., 2013; see Ohly et al., 2016 for a review on visual and physical exposure). ART serves as the basis for the Perceived Restorativeness Scale (PRS) questionnaire developed by Hartig and colleagues (1997). Nevertheless, the aforementioned characteristics of a restorative environment have also received criticism for lacking clear operationalizations, empirical evidence (for soft fascination) and for inconsistencies in measurements of directed attention depletion and restoration (Neilson et al., 2019).

The final idea concerns aesthetic preference for natural environments, which will be part of the focus of this paper. First evidenced experimentally by Kaplan (1972) after attempting to disentangle the respective roles of complexity and content in aesthetic preference, studies have established links between aesthetic preference and natural environments (Hoyle et al., 2017; Kardan et al., 2015; Ode et al., 2009; Tveit et al., 2006) but also with restorative potential (Hidalgo et al., 2006; Korpela and Hartig, 1996; van den Berg et al., 2007). In other words, the restorative potential of an environment may be related to how aesthetically appealing it is. Indeed, proponents of ART have advocated that the aesthetic preference for natural over urban environments owes to the perceived restorativeness of such environments (Han, 2010; Hartig and Staats, 2006; Herzog et al., 2003; Laumann et al., 2001; van den Berg et al., 2003) – particularly if individuals are cognitively fatigued and searching to replenish their depleted directed attention (Hartig and Staats, 2006). What is less clear is whether aesthetic preference is related to naturalness *per se,* or perhaps to confounding factors, such as low-level features (e.g. color, contrast, straight edge density; Berman et al., 2014; Kardan et al., 2015), high-level semantics (the meaning associated to objects in a scene; Hunter and Askarinejad, 2015; Ibarra et al., 2017), or even other factors, most notably fractal geometry (Hagerhall et al., 2004; Joye, 2007; Joye and van den Berg, 2011; Purcell et al., 2001; Spehar et al., 2003; Taylor, 2006). Indeed, aesthetic preference has also been shown to be linked with the fractal dimension of a scene (Hagerhall et al., 2004) or artwork (Taylor, 2002; Taylor et al., 1999). Fractal dimension (henceforth, *D*) refers to the scale invariance of a pattern, or the conservation of a pattern throughout increasingly fine magnification. It can also be defined as a measure of "the extent to which a structure exceeds its base dimension to fill the next dimension" (Hagerhall et al., 2004). For a fractal line, *D* will be between 1 and 2, and for a fractal surface between 2 and 3. Work by R. Taylor in collaboration with NASA has demonstrated that a certain *D* value range is necessary for stress reduction to occur (Taylor, 2006; Wise and Rosenberg, 1988; Wise and Taylor, 2002), and that "naturalness is not enough to induce physiological responses—specific [*D*] values are required" (Taylor, 2006). Although researchers have demonstrated that many natural scenes are high in fractal dimension (Barnsley and Hurd, 1989; Gouyet and Bug, 1997; Mandelbrot, 1982; Peitgen and Saupe, 1988; Voss, 1988) some (urban) architectures also appear to score high in this regard, e.g. Gothic cathedrals (Goldberger, 1996), Buddhist temples (Taylor, 2006). The role of naturalness in aesthetic preference thus remains unclear. If we find nature beautiful, is it because of an ancestral pull towards our evolutionary habitat, an aesthetic appeal to certain image features (colors, fractality), a semantic attraction to meaningful objects, or other factors?

I / What does Nature consist of?

The first challenge in environmental psychology, and specifically in studying the effects of nature on the human psyche, is to define of what exactly nature consists. Surprisingly, only little research has attempted to establish this thoroughly, and as such, nature often tends to be defined rather intuitively as environments devoid of manmade presence (Mausner, 1996; Wohlwill, 1983). As put by Wohlwill, the natural environment refers to:

> "[…] the vast domain of organic and inorganic matter that is not a product of human activity or intervention. It is, in other words, defined largely by exclusion. It deals with the landscape rather than with the built environment. It includes the world of rock and sand, of shoreline, desert, woods, mountains, etc., and the diverse manifestations of plant and animal life that are encountered there. It excludes the man-made world: our cities and towns, our houses and factories, along with the diverse implements devised by mankind, for transport, recreation, commerce, and other human needs."

By extension, naturalness has been defined by I. M. Sztuka (unpublished) as the following:

> "Naturalness […] are physical properties of the object, scene or environment, which represent or mimic the properties available in the organic world."

According to these two researchers, the presence of human artificialization detracts from the concept of nature (and naturalness), and therefore the most natural environment is one which shows no signs of human artificialization whatsoever. However, this definition may seem ambiguous. For example, landscapes which show no human artefacts *per se* may yet show 'traces' of artificialization. Wohlwill contends that depending on the landscape, this artificialization may have differing impacts on the individual's psychological response. If the sight of a dam or other kinds of artificialization were withheld from an individual viewing a lake, i.e. if they didn't know it were an artificial lake, their psychological response might be similar as if the lake were natural. On the other hand, in landscapes such as an orchard or farmland, where artificialization is evident through the uniformity and regular spacing of crops, psychological responses might be quite different than if the landscape did not show those signs. These noticeable signs of anthropization exclude the landscape from being included in what we call the "world of nature" (Wohlwill, 1983). Wohlwill adds two more critical points with regards to defining nature. First, signs of anthropization are ever-present even in the most remote natural landscapes (artefacts such as roads, powerlines, buildings…), and therefore, the criterion for naturalness ought to be lenient so as to include environments with manmade presence "provided that the natural aspects remain predominant over the built ones" and that the environment "remains identified as natural or scenic in terms of the use made of it" (Wohlwill, 1983), thereby incorporating the issue of place functionality. A place, landscape, or environment is natural if it has a natural function. Secondly, "imported nature", i.e. parks, gardens, a flowerbed on the balcony of an apartment, are evidently not natural, yet should also be included in our consideration of human response to the world of nature because there is "no denying the strong element of nature contained in such environments, in the sense of organic, and more particularly, plant life" (Wohlwill, 1983). Here, an argument opposed to the 'definition by exclusion' is raised, since nature is defined 'positively', namely by the presence of life and plants albeit in a predominantly urban environment. The presence of vegetation and water is a recurrent 'positive' conceptualization of nature (Hur et al., 2010; Kellert and Calabrese, 2015; Kellert and Wilson, 1993; Ulrich, 1993; Ulrich et al., 1991), in agreement with the biophilia hypothesis, or more specifically, to phytophilia (Joye and van den Berg, 2011). Nonetheless, the lack of a clear definition of nature and naturalness (e.g. How does a space function as natural? What does it mean for natural aspects to be predominant over built ones?) leads to the problem of the operationalization of nature in environmental psychology studies.

Because of the heavy reliance on nature's 'definition by exclusion', a major dichotomy in this field consists in contrasting natural and built environments (Velarde et al., 2007). These are often taken as whole and opposed, suggesting a fundamentally binary relationship between the two (see Figure 1). This is a common paradigm used to study the potential effects of nature on the psyche (e.g. Grassini et al., 2019; Hartig et al., 2003; Kaplan et al., 1972; Kardan et al., 2015; Stevens, 2014; Ulrich et al., 1991; van den Berg et al., 2003; Velarde et al., 2007). However, one may wonder whether this is an accurate way of framing our environment: Is an environment either built or natural? Some researchers have advanced that studying the effects of nature by opposing nature and built environments may not capture the proper of nature in itself, but rather the absence of the alternative condition. For example, in line with SRT, many natural environments are devoid of stressors found commonly in urban environments, such as traffic (Bowler et al., 2010). Furthermore, 'imported nature', of which parks and urban nature may also be referred to as 'green infrastructure', raises the idea that some environments may lay somewhere in between the natural/built dichotomy. For example, the Emerald Necklace consists of 450ha of parks linked by parkways and waterways, intertwined into the dense urban center of Boston, USA. When walking in such an environment, one might feel both in nature and in a built environment simultaneously. Referring to the example mentioned earlier, it is difficult to assess how natural or manmade an orchard filled with neatly organized apple trees is (see Figure 2). Is it natural because it consists of greenery, life, and is devoid of human artefacts, or is it built because of the visible signs of anthropization and the function of the orchard is neither natural nor scenic?

Figure 1. The natural-urban dichotomy is a common operationalization in environmental psychology. Here, there is a clear-cut distinction between built and natural environments. Left: A natural landscape in New Zealand (photographer: Emily-Rose Ashdown). Right: A residential area in the United Kingdom (photographer: Ann Hodgson).

Figure 2. Examples of ‘natural’ environments showing traces of anthropization. In these images, the distinction between naturalness and anthropization seems more complex. Left: Rice fields in Vietnam (photographer: Simon Gurtney). Right: An orchard in the Netherlands (photographer: Ina Van Hateren).

Hence, although it might be somewhat practical for purposes of research design, it seems imprecise to classify environments as strictly built or strictly natural (Karmanov and Hamel, 2008). Therefore, researchers have been attempting to nuance this distinction by further understanding what environments represent subjectively and objectively in terms of naturalness and anthropization. For example, some researchers have attempted to identify the naturalness of a scene from the standpoint of participants’ subjective rating (Hur et al., 2010; Ode et al., 2009). Other research has set out to identify the objective measures of naturalness, such as the research group of Marc G. Berman in Chicago, USA. Berman and colleagues (2014) obtained data from 52 participants, including their ratings on naturalness and aesthetic preference, from 307 images of mixed built and natural environments. By extracting low-level features from each image (i.e. color and spatial properties) and pairing them with participants similarity, naturalness, and preference ratings, they created a classifier which could predict naturalness and aesthetic preference with high accuracy (81%). Non-straight edge density (NSED), straight-edge density, hue, hue standard deviation, and saturation standard deviation all significantly correlated with naturalness. NSED, which includes curved contours, was the strongest predictor. Kardan and colleagues (2015) replicated this study, at least insofar as low-level features predicting naturalness, and found similar correlations between NSED, hue, and naturalness ratings. Of note, they also showed that naturalness modeled by these low-level features could predict aesthetic preference. The importance of NSED was further stressed by Schertz and colleagues (2018), where NSED and naturalness ratings were consistently correlated through presentation of images of parks, as well as with certain thought topics, such as “Spirituality and life journey”. This research was further advanced by correlating high-level semantic features of the 307 images with naturalness and aesthetic preference ratings. Hunter and Askarinejad (2015) established 62 high-level features (e.g. “Skyline Geometry”, “Water Expanse”, “Building Distribution”), 10 of which were used by Ibarra and colleagues (2017) to analyze Berman’s 307 images. They found that the high-level features were even stronger predictors than the low-level features, and crucially, that high-level features mediated in great part the predictive power of the low-level features. In their words, ““water” might be a large predictor, but the form of the water and its landscape layout and/or design is accounting for more of the modeled predictions.”

The relevance of high-level semantics was further showcased in a study operationalizing the “nature-disorder paradox”, which frames the following: How can nature be aesthetically pleasing if nature is disorderly and disorder is displeasing? The nature-trumps-disorder hypothesis (aesthetic preference for nature is more powerful than aesthetic aversion to disorder) was found to resolve this paradox, and crucially, high-level semantics were both necessary and sufficient for this effect to occur. The nature-trumps-disorder effect was absent when scene semantics were removed by rapidly presenting images or by scrambling image features, and returned when only the scene semantics were present and image features were removed (by presenting noun stimuli; Kotabe et al., 2017). Another study (Van Hedger et al., 2019a) demonstrated the importance of semantics in sound recognition, and in preference for natural sounds (e.g. birdsong) over urban sounds (e.g. café chatter). In one experiment, semantic features of natural or urban soundscapes were obscured, either by scrambling the time-domain of the audio file or by presenting only a thin-slice (100ms), versus an unaltered condition. Nature-related aesthetic preference was robustly observed in the unaltered condition, attenuated in the scrambled condition, and absent in the thin-slice condition. In another experiment from the study, identical sounds were more preferred when previously categorized as natural rather than urban. Similarly, Haga and colleagues (2016) presented the same sound to two groups, but told one group that it originated from a waterfall and the other from industrial machines. Although they did not measure aesthetic preference, they found that restoration was higher for the waterfall group. All three of these studies lend support to the idea that high-level semantics play a key role in our conceptualization of nature, as well as in the relationship between naturalness, aesthetic preference, and restoration. Put otherwise, how we consider and react to nature may owe more to a top-down, meaning-driven process rather than to a bottom-up sensory- or stimuli- driven process.

Finally, it should be mentioned that color plays an important role in our perception of naturalness. In particular, green is associated with nature through vegetation (aka ‘greenery’), and blue is associated with the sky and water. As such, these two colors are main components of nature - although a case could be made for non-green natural environments, such as deserts of sand or ice. Ulrich (1991) and other proponents of the biophilia hypothesis cite that vegetation and water (in addition to the absence of manmade presence) are the hallmarks of natural landscapes. Stephen Kellert, the co-founder of the hypothesis, goes further in saying that positive feelings associated with natural (living) systems could by extension be associated with green and blue (Kellert et al., 2011). Ibarra and colleagues (2017) found that water and non-veiling vegetation were positive predictors of perceived naturalness. Since hue was also a predictor, it could be the case that we respond to the colors of green and blue as natural by association, independently of the semantic content of the image. This has led to many applications of color in biophilic design: green and blue particularly, but also “earthy” colors such as brown and yellow, and even red which is associated with warmth and fire (Kellert, 2018; Kellert and Calabrese, 2015). In a recent study using indoor plants, it was found that visible greenness rate, measured as the percentage of the participants’ eye-field, correlated highest with perceived naturalness, as opposed to green coverage ratio (floor area in squared meters occupied by plants) or viewing distance (Han, 2020). This corroborates the importance of color as an objective measure for the perception of naturalness.

Combined, this research establishes both low-level visual (color, spatial properties) and high-level semantic features as objective contributors to the perception of naturalness, aesthetic preference, and even the content of thought. Although nature is often defined as the absence of manmade presence, and operationalized binarily with man-made environments, a more nuanced framework to study the potential effects of nature on the human psyche would be to consider naturalness as a gradient, attested by the presence of certain features (low-level and high-level) and combined with participants subjective ratings.

II / Aesthetic preference

Aesthetic preference for naturalness can be traced back to the origins of civilization and throughout human history. In ancient Mesopotamia, the hanging gardens of Babylon, medieval China (Olonetzky, 2017), Aztec chinampas (Evans, 2017) and Cistercian monasteries in Europe (Landsberg, 2003), nature has been intentionally incorporated into our urban landscapes for farming, but also for beauty's sake alone, in the form of gardens, flowers, trees, or frescos. In environmental psychology research, it has been established that natural environments are consistently rated higher than typical urban environments in aesthetic preference (Hartig and Staats, 2006; Kaplan and Kaplan, 1989; Kardan et al., 2015; Purcell et al., 2001; Ulrich, 1993; van den Berg et al., 2003). Aesthetic preference is mainly measured through like/dislike affective responses, as established by Zajonc (1980). As such, to assess aesthetic preference for an environment, much research uses Likert scales, through a single question or through a questionnaire (e.g. Berman et al., 2014; Kardan et al., 2015; van den Berg et al., 2003). This implies a heavy reliance on subjective ratings and seems in line with the idea that 'beauty is in the eye of the beholder'. However, it overlooks a major theme in philosophical literature which is the tension between universality and subjectivity. Although aesthetic experiences do, evidently, depend on subjective judgments, they can be so universally consistent across individuals as to be termed universal (Vessel et al., 2012). For example, there is wide agreement on the beauty of flowers (Scarry, 1999). In environmental psychology, the objective approach to aesthetic judgement seems largely to be left out, as the study is primarily concerned with the qualities of preferred environments rather than the particular mechanisms of people's response to them. The field of research that does take interest in these objective (i.e. biological) measures is a nascent, "promising" field, called environmental neuroscience (Berman et al., 2019). More generally, the study of objective responses to aesthetic experiences refers to the field of neuroaesthetics (Chatterjee and Vartanian, 2014). Before moving on to the literature in environmental psychology, the theoretical frameworks and contributions of these two fields shall be overlooked.

From a theoretical standpoint, the aesthetic experience has been linked to three systems in the brain forming an “aesthetic triad”: sensory-motor, emotion-valuation, and knowledge-meaning (Figure 3). This framework allows for mapping different stages of information processing onto neural structures.

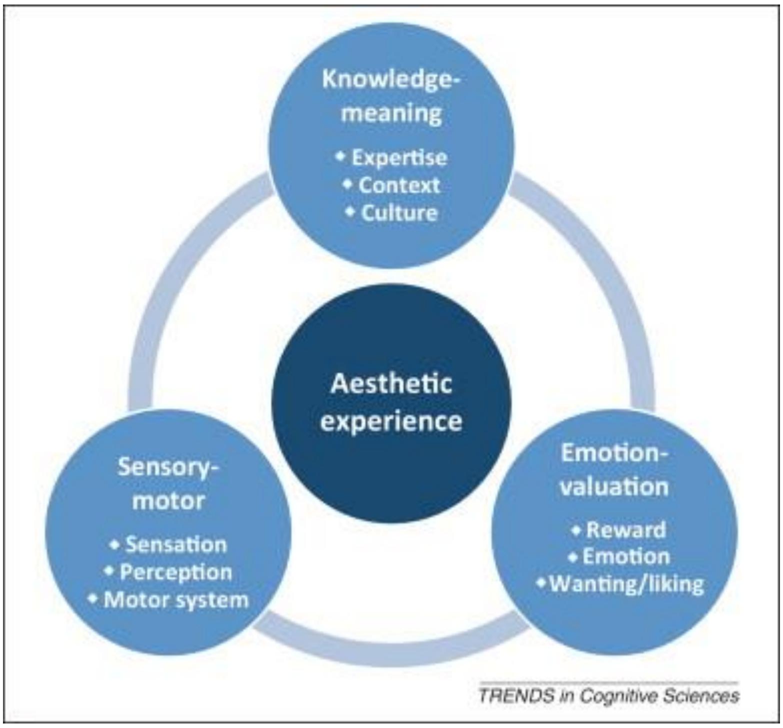

Figure 3. The aesthetic triad. In the brain, sensory-motor, emotion-valuation, and knowledge-meaning systems interact to form an aesthetic experience. Taken from (Chatterjee and Vartanian, 2014).

In sensory-motor systems, the earliest processing of visual aesthetics, such as shape and color, occurs in occipital lobe. Higher processing (faces: Kawabata and Zeki, 2004; places: Yue et al., 2007) occurs in the medial temporal lobe, and implicit actions in parts of the motor system (mirror neuron system; Umilta et al., 2012). In occipito-temporal regions, blood-oxygen level dependent (BOLD) response has been shown to increase linearly from baseline (resting condition) for different levels of aesthetic preference (Vessel et al., 2012). Emotion-valuation systems, such as orbitofrontal and medial frontal cortex, ventral striatum, anterior cingulate and insula, are involved in aesthetic experience since, for example, reward circuitry is activated when looking at beautiful objects or faces (Chatterjee, 2009; Chatterjee and Vartanian, 2014; Kim et al., 2007; Kühn and Gallinat, 2012). In the striatum (reward) and pontine reticular formation (arousal), BOLD responses increase and decrease linearly from baseline for preferred and non-preferred aesthetics (Delgado, 2007; Löw et al., 2008;

Vessel et al., 2012). Knowledge-meaning systems are distributed largely across the brain and vary substantially across individuals and cultures, but their implication is made clear by studies that manipulate the context under which stimuli are viewed, as they modulate activity within emotional and reward circuitry (Chatterjee and Vartanian, 2014). For example, knowing the title of an artwork can elicit greater aesthetic engagement, and knowing that it is an original piece or a copy can generate different neural responses (Huang et al., 2011; Leder et al., 2006). Greater activation in medial orbitofrontal and ventro-medial prefrontal cortex was found for abstract art images when participants were told they were from a museum, rather than computer generated (Kirk et al., 2009).

However, separate networks are recruited when aesthetic experience is at its peak (i.e. rated highest), namely frontal regions, subcortical regions, and the default mode network (DMN; Vessel et al., 2012). The involvement of the DMN when aesthetic experience is at its peak is surprising, since DMN is usually activate when “off-task” – when participants are told to think about “nothing”. In a follow-up study, Vessel and colleagues (2013) suggest that DMN can also be mobilized when tasks involve self-referential thought or self-relevant information. In this sense, it is hypothesized that the DMN activation would reflect an internal orientation evoked by an external stimulus during a deeply aesthetic moment, which seems to be one of the mental hallmarks for profound aesthetic experiences – being “moved’ or “touched from within” (Chatterjee and Vartanian, 2014; Vessel et al., 2013). Furthermore, research has found that aesthetic response occurs in two temporal steps. Using magnetoencephalography, Cela-Conde and colleagues (2013) identified one neural pattern around 250ms after exposure to artwork, and one around 1000 – 1500ms. The second response, but not the first, was tethered to DMN activation, and has been interpreted according to the appraisal theory of emotions, which posits that subjective desires and goals mediate emotional responses to objects and events in the world. Combined with the previous finding, the delayed response of the DMN could therefore be what encompasses the subjectivity of aesthetic experience, since it would explain why “the same painting can evoke anger in one person, curiosity in another, and amusement in a third” (Cela-Conde et al., 2013; Chatterjee and Vartanian, 2014; Silvia, 2012).

On the other hand, although individuals have different reactions to different images in accordance with their personal relevance, “such experiences are universal in that the brain areas activated by aesthetically moving experiences are largely conserved across individuals” (Vessel et al., 2012). With regards to environmental preference, this suggests that although different people like different environments, the mechanisms for liking an environment could be universal. This would provide equivocal support for the theories in place. If our own subjective desires and goals, mediated by our DMN response, create a liking or disliking by recruiting subcortical and frontal regions, then aesthetics seem more subjective than objective. In that case, a hard-wired preference for natural environments seems unlikely since nature wouldn't necessarily align with the subjective desires and goals of everyone. However, the studies mentioned above mostly concern artwork, such as paintings, which are not equivalent to environments. Although both can be the subject of aesthetic preference, artworks hold little to no 'functional' value bar decorative purposes, whereas some of the theoretical underpinnings in evolutionary and environmental psychology hold that it is the functional value of nature that may play a role in our inclination towards it (e.g. safety, food, shelter, prospect, being away…). Therefore, equating artwork and environments in terms of subjective preference would seem fallacious in omitting the functional relevance of environments as opposed to artworks. On the other hand, if an aesthetic experience is highly "moving" because it allows for introspection and internal orientation, then our preference for nature could stem from the fact that nature may be the kind of environment that allows for those mental processes to occur. Particularly when taken in contrast with urban environments, natural environments offer less noise pollution (Dzhambov and Dimitrova, 2014), less cognitive load (Valtchanov and Ellard, 2015), and less expectancy for social stimulation (Staats et al., 2003) than their urban counterparts, thereby potentially allowing for DMN response. Moreover, DMN has been associated with practices of mind-wandering (Smallwood and Schooler, 2015) and meditation (Simon and Engström, 2015), both of which are introspective and have been linked to restoration (Kaplan, 2001; Lymeus et al., 2018; Williams et al., 2018).

In line with this idea, many authors argue that perceived restorative potential (PRP) could be the driving force of aesthetic preference for natural environments (Han, 2010; Hartig and Staats, 2006; Purcell et al., 2001; Staats et al., 2010; Ulrich, 1993; van den Berg et al., 2003; Wang et al., 2019). Purcell and colleagues (2001) found that PRP correlated strongly with environmental preference ($r = .81$) and concluded that restorative value could have been used as an implicit frame of reference for making a preference judgement. Hartig and Staats (2006) corroborated this finding in a study operationalizing attentional fatigue. A non-fatigued group (before a lecture) and a fatigued group (after a lecture) were taken to walk either in a forest or in a city-center. Although both groups preferred a walk in the forest, the difference in PRP between the two environments was higher for the fatigued group than the non-fatigued group and correlated with environmental preference, thereby showing that individuals in need of restoration also prefer the environment which is most likely to restore them.

Crucially, however, the environment alone cannot account for the relationship between environmental preference and restoration. Various research has shown that professional occupation, activity, social context, and familiarity can mediate this relationship. For example, Von Lindern and colleagues (2013) showed that individuals working in a forestry environment received less restoration from visits to the forest than non-forest professionals, which may be due to a diminished sense of “getting a break” from their routine. Staats and colleagues (2010) demonstrated the importance of activity-in-environment and social context, by contrasting leisure time spent at home, in a park, in a city center, or in transit. When fatigued, individuals preferred to be alone and in nature. However, non-fatigued individuals preferred being in company and in other environments. This was followed up in a similar study in 2016 (Staats et al., 2016), where it was found that restoration needs (fatigued versus non-fatigued), country of residence, social context, and activity all played significant roles in preference and likelihood of restoration within different urban environments. Collado and colleagues (2015) established that children with a work relationship to the countryside (among other factors, such as social context) experienced less restoration when doing leisure activities there, compared to children that went to the countryside only for leisure. Overall, the relationship between restoration potential and environmental preference cannot be attributed to the environment alone. A multitude of factors come into play. Again, this corroborates the idea that restoration and preference for natural environments may stem from a top-down, meaning-driven mechanism rather than a bottom-up, stimulus-driven mechanism.

Hoyle and colleagues (2017) found an additional complexity in the relationship between PRP and aesthetic preference. In comparing various degrees of flower coverage in an urban setting, higher flower coverage was viewed as more aesthetic and higher green coverage as more restorative. Authors attribute this in part to the fact that the sample population was more biocentric than average as they stemmed from study backgrounds relating to environmental sciences, ecology, and landscape management. It was revealed in qualitative interviews with the participants that flower coverage was “often more vibrant and colorful, had more detail, and demanded more attention”, whereas green planting was seen as “less detailed, providing the background for other thoughts or conversations.” A weak correlation was found between aesthetic preference and PRP in general, contrary to the strong correlation found by Purcell and colleagues (2001). In agreement with the finding from the previous paragraph, professionals from landscape management experienced less restoration than non-professionals. The different findings for flower and green coverage raise a distinction with regards to the driving effect of PRP on aesthetic preference, suggesting that they might not be as tightly coupled as demonstrated in other studies. The most aesthetic environment is not necessarily the most restorative and conversely, the most restorative is not necessarily the most aesthetic.

So far, studies have focused on environmental preference through perception, and namely visual perception. However, is beauty only visual? Other modalities, such as auditory and audio-visual interactions have been found to promote restoration (mood improvement: Benfield et al., 2014; attention restoration: Abbott et al., 2016; Van Hedger et al., 2019b; Jahncke et al., 2015; perceived restorativeness: Payne, 2008; Ratcliffe et al., 2013; Wilson et al., 2016; Zhao et al., 2018; stress reduction: Alvarsson et al., 2010) and could therefore be important factors in environmental preference. Olfactory and haptic perceptions have not received substantial scientific interest with regards to restoration. This seems to be due to the dominant operationalization of these studies, as stimuli are mostly shown through computer screens. At best, this includes a headset to play sounds, but the incorporation of fragrances and artificial wind has yet to become standard. The practice of outdoor studies (e.g. Berman et al., 2012; Hartig and Staats, 2006; Taylor and Kuo, 2009) should therefore be encouraged, and perhaps seek to include subjective and/or objective measures of smell and touch. This may help to gauge the contribution of these senses to environmental preference, and by extension the relative importance of the audio-visual modalities. For example, in a recent virtual-reality (VR) study (Browning et al., 2019), participants were exposed during 6 minutes to either outdoor nature, VR nature, or an indoor control environment. Physiological stress (skin conductance), mood (Positive and Negative Affect Schedule; Watson et al., 1988) and restorativeness (PRS) were measured. Although both outdoor and virtual nature increased arousal and perceived restorativeness compared to the control condition, only the outdoor condition improved mood. The VR condition preserved mood but did not improve it. Since the 360-degree VR environment was recorded at the same location as the outdoor condition, visual and auditory stimuli would have been similar. This may suggest that the other modalities of the outdoor condition (i.e. natural fragrances or haptic sensations) could have participated in the shift in positive affect present in the outdoor condition but not in the virtual one. It could also suggest, more simply, that VR experiences do not (yet) fully encompass the experience of being outdoors. However, some other research has found improved positive affect from simulated nature (McMahan and Estes, 2015). Aside from perceptual modalities, perceived restoration of an environment can also be linked to self-constructs, such as place identity. For example, Wilkie and Clouston (2015) found that for self-identified "city" people, urban environments can be at least equally preferred and equally restorative as natural environments. In this sense, many factors, including non-visual sensory modalities and self-constructs, can contribute to environmental preference and restoration. Importantly, the inclusion of self-constructs again strengthens the idea of a meaning-driven process, since the same environment can be restorative to some people and aversive to others, based on how strongly they identify with it.

Finally, an outstanding question is whether we would value nature simply because of aesthetic preference, or rather because of something special that would be proper and inherent to nature. In the aptly named study “What’s nature got to do with it?”, Meidenbauer and colleagues (2020) shed some light on this question by comparing visual stimuli from natural and urban environments in a series of experiments. First, they had participants classify images according to naturalness and aesthetic preference. Then, they set out to compare the urban and natural image’s effect on mood while controlling for preference – for example, highly preferred nature images versus highly preferred urban images. Mood was assessed with a Positive and Negative State Trait Anxiety Inventory (Marteau and Bekker, 1992) before and after image viewing. They found significant relationships between aesthetic preference and mood change, regardless of environment (natural or urban), providing evidence that there is nothing special about nature – if an urban environment is beautiful enough, it may be restorative just the same. However, interestingly, there was a ‘Very High’ aesthetic value category for natural images that went unmatched for urban images. Likewise, there was a ‘Very Low’ aesthetic value category for urban images that was not found for natural images. In other words, in the image sample, there were very few strongly liked urban images, and very few strongly disliked nature images. The authors addressed this in the following experiments by incorporating only images of most preferred stimuli from three categories: nature, urban, and animals. It was hypothesized that if nature had ‘something extra’, then it should yield an increased change in mood compared to the urban and animal stimuli for the same preference level. In addition, to assess whether baseline mood would have an effect on the change in mood provoked by the image viewing, they had half of the participants pass a ‘neutral’ mood induction procedure and the other half a ‘negative’ one. Thus, they could assess if starting off with a bad (or neutral) mood would lead to more increase in mood change after image viewing. This proved to be the case, as mood induction type had a significant effect on mood change. Average personal rating of the presented stimuli also had a significant effect. However, once again, image type (nature, urban, or animal) had no significant effect. Thus, regardless of stimuli category, be it nature, urban, or animal, highly preferred stimuli have a similar effect on mood, namely an increase in positive and decrease in negative.

Importantly, the authors stressed the difficulty of finding images of equivalent preference for each category. This leads to the possibility that the distributions for natural scenes compared to urban scenes with regards to aesthetic preference are shifted: it may be easier to find 'beautiful' images of nature and 'ugly' images of urban environments than the reverse. This is schematized in Figure 4. This could potentially explain the differences in restoration found in the two types of environment. Driven by aesthetic preference, nature would simply happen to be more beautiful than built environments. This leads to the following question: why would nature be more beautiful than man-made environments? In the following section, we shall shed light on some of the theories that attempt to explain this.

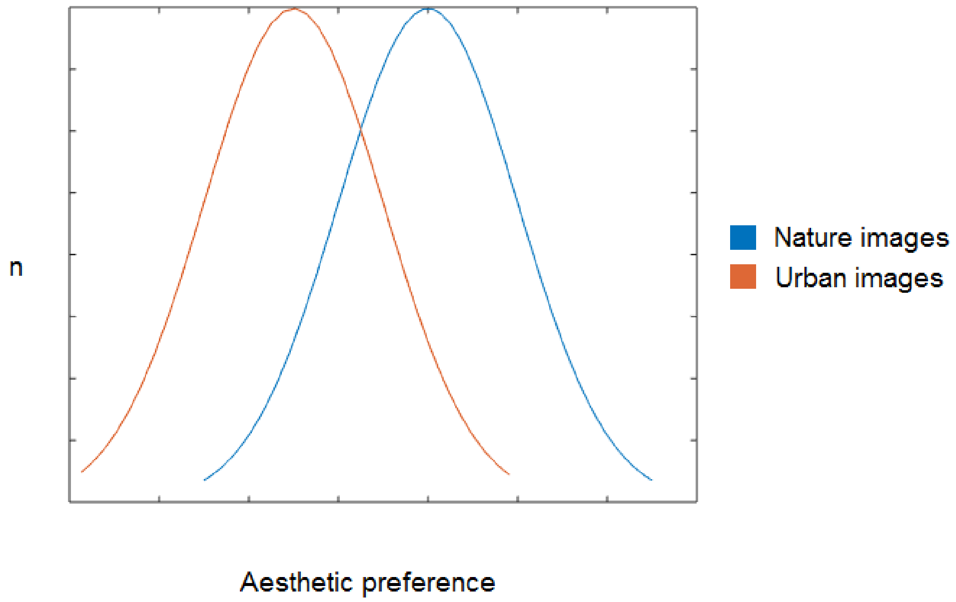

Figure 4. Hypothetical distributions for natural and urban scenes

III / Why do we find nature beautiful?

Many theories, including the biophilia hypothesis, have attempted to characterize and understand the human-nature relationship through an evolutionary lens. The savannah hypothesis was developed by Orians (1980) and states, akin to the biophilia hypothesis, that humans are adapted to the environment they evolved in for much of their existence – namely, the African savannah. Although there is clearly a mismatch between our current environment and this putative ancestral habitat (Buss, 2000), it is argued that a preference for this landscape, and by extension its features, is deep-seated in our psyche resulting from millennia of evolution (Kellert and Calabrese, 2015). Components of the savannah that contributed to the survival and well-being of ancestral humans are grouped into categories of resource availability and protection. For example, high diversity of plant and animal life and bodies of water offer access to resources, whilst open grasslands, large horizons, and scattered clusters of wide-canopy trees offered a clear view of the surroundings and protection. In this theory, Orians (1980) links the affective response to a landscape with the search and identification of a suitable habitat – good habitats will yield more positive responses and unsuitable habitats less positive responses. Orians and Heerwagen (1992) posit the existence of a "generalized bias towards savannah-like environments […] even in the absence of direct experience." Support for this theory comes from a study from Balling and Falk (1982), where children preferred savannah scenes rather than natural scenes from their own proximate environment of Northeastern America. However, the adults in this study preferred both the familiar scenes and the savannah scenes. The authors later replicated the study in 2010 – this time with students and children from the rainforest regions of Nigeria, similarly with no 'direct experience' of the savannah. The participants also displayed a preference for the savannah-like environments. The authors suggest that the preference for savannah is present in childhood but declines with experience, as a result of familiarity and enculturation to different environments. (Orians and Heerwagen (1992) therefore claim that savannah preference could be an innate, evolutionary trait. Lohr and Pearson-Mims (2006) found that trees with spreading canopies (i.e. savannah trees) were aesthetically preferred and yielded more positive emotions than inanimate objects or other tree forms. On the other hand, Han (2007) compared six major biomes' (e.g. desert, tundra, grassland) effects on perceived restorativeness and aesthetic preference. Contrary to the former studies, participants' preference and restorativeness were unfavorable to the grassland (savannah) biome, ranking fifth out of six in both measures. Furthermore, the theoretical assumptions underlying the savannah hypothesis, namely that the African savannah would consist of our environment of evolutionary adaptedness, have received harsh criticism (Domínguez-Rodrigo, 2014; Joye and De Block, 2011). Chronologically, the support for a 'savannah hypothesis' seems to be on a downwards trend.

Prospect-refuge theory was first developed by geographer Jay Appleton in 1975 (Appleton, 1996), as an extension of his habitat theory. Drawing from the Darwinian idea that 'survival instinct' would connect human perceptions and reactions to stimuli from the environment, habitat theory posits that pleasure is related to environmental conditions necessary for survival, namely "the ability of a place to satisfy all of our biological needs" (Appleton, 1996). As a further development, prospect-refuge theory asserts that humans strategically appraise landscapes as potential habitats that enable the ability to "see without being seen". Arguing that people prefer being in places where they can effectively monitor their environment (prospect) whilst simultaneously remaining safe (refuge), Appleton claims that these would have been preferred environmental conditions during evolution to protect from “hazards” such as predators, weather, etc. Therefore, Appleton’s idea is that humans evaluate environments functionally through prospect and refuge, and that these have shaped our sense of environmental aesthetics (Dosen and Ostwald, 2013). Hildebrand (1993, 2008) has demonstrated support for this theory, arguing that many architectural designs with long lasting appeal rely on prospect and refuge components. He also added several spatial dimensions to the theory, such as complexity and order. Prospect-refuge theory has since then gained traction in the field of environmental psychology, but more so in landscape management, architecture, and interior design (Dosen and Ostwald, 2013). Several other authors have contributed to extending the theory. For example, Stephen and Rachel Kaplan’s ‘informational perspective’ (Kaplan and Kaplan, 1989; Kaplan et al., 1982) posits that environmental preferences result from an innate sensitivity to information requirements for survival. They argue that ancestral humans would have been selected for cognitive abilities enhancing the comprehension of extended spatial areas – namely through rapid information processing and way-finding. Thus, the comprehension of an environment would not only shape a preference for it but also allow for its further exploration. These two attitudes (exploration and understanding) are associated with four landscape properties that form the basis of the ‘preference matrix’: complexity, mystery, coherence, and legibility. In exploring an environment, complexity refers to “how much is ‘going on’ in a particular scene”, and mystery to the suggestion that more information could be acquired if the scene were further explored (e.g. a trail going out of sight). In understanding an environment, coherence refers to the features contributing to the organization, understanding, and structuring of the scene, such as symmetries or repeating patterns, and legibility refers to components that help predict/maintain orientation in the landscape as it is explored, like an oddly shaped tree or a prominent rock (Kaplan, 1987; Kaplan and Kaplan, 1989). SRT also details some examples of properties predicting preference or positive affect that overlap to an extent with prospect-refuge theory and Kaplan’s informational perspective: complexity, gross structural properties (coherence), absence of threats (refuge), deflected vista (mystery) (Ulrich, 1983).

The main limitation of these frameworks is that they rely on qualitative assessments of environmental preferences – let alone the unreliability of their evolutionary assumptions. As such, Dosen and Ostwald (2016) meta-analyzed the quantitative evidence for prospect, refuge, mystery and complexity, in landscapes, urban settings, and interiors. From the 34 studies that were included, the quantitative evidence for prospect-refuge theory was inconsistent as a whole. In landscape preference, both prospect and refuge were supported (6/9 and 5/8 studies respectively). However, in interiors, refuge was not supported (2/17 studies). Complexity was supported regardless of venue, and mystery was overall unsupported. The authors concluded that the factors predicting preference in landscapes should not necessarily be generalized to interior design, which has been the case throughout the development of the field of study – especially for refuge. Furthermore, although there was support for complexity, it is unsure about “how much” or “where” it should be, as the measures and evidence for complexity as a predictor were equivocal. Therefore, although prospect-refuge theory and its extensions may provide some insight into the features of landscape preference, those features are hypothetical as they rest on hotly debated evolutionary assumptions, are empirically inconsistent as a whole, and are ungeneralizable to other instances of aesthetic preference.

Other studies have mentioned the importance of visual ‘openness’, i.e. the ability to see without one’s view being blocked, as a landscape feature predicting aesthetic preference (Galindo and Hidalgo, 2005; Herzog et al., 2003; Hidalgo et al., 2006; Pazhouhanfar and M.S., 2014; Tveit, 2009). This overlaps with the concept of prospect, with the idea of having a clear view of one’s surroundings. In the meta-analysis by Dosen and Ostwald (2015), prospect was supported in interior design, where open rooms where mostly preferred to enclosed ones. In a study on landscapes, Tveit (2009) found that visual scale (including openness) had a significant effect on preference: particularly, there was a preference for half-open landscapes over very open landscapes and closed landscapes. In urban environments, Galindo and Hidalgo (2005) identified openness as a factor increasing restoration potential (along with Harmony, Luminosity, Suitability for leisure and Meeting place). The importance of openness was also corroborated in the high-level semantics study of Ibarra and colleagues (2017): the most preferred scenes contained open views, and the least preferred scenes contained blocked views - even by vegetation. In this sense, the importance of openness could even trump the importance of greenness. However, Herzog and colleagues (2003) found a negative partial correlation between openness and PRP. Therefore, the evidence for openness in predicting the preference or restorativeness of an environment is not unanimous and also varies when taking the type of environment (interior, urban, landscape) into consideration.

Another theory proposes that perceptual fluency may drive our restorative response towards natural environments. The main assumption of perceptual fluency is that natural environments are processed more fluently than their urban counterparts, which leads to a difference in restorative potential. It is posited that the visual brain is more tuned to the structure of visual information in natural scenes and specifically, to the concept of fractality (self-similar patterns, see Figure 5 and 6; Joye and van den Berg, 2018). Again, drawing on evolutionary arguments and a stimulus-driven perspective, it is argued that our perceptual system is more familiar with fractal geometry (Rogowitz and Voss, 1990) since this has been found to be omnipresent in natural scenes (Barnsley and Hurd, 1989; Gouyet and Bug, 1997; Mandelbrot, 1982; Peitgen and Saupe, 1988; Voss, 1988). On the other hand, Euclidean geometry, i.e. circles, squares, or cubes, is very rarely encountered in nature, but emerged abundantly (and relatively recently) in our built environments (e.g. houses, streets, man-made objects). Purcell and colleagues (2001) speculate that the high restorativeness of nature could be due to its underlying fractal geometry, and the low restorativeness of urban environments to its Euclidian characteristics.

Figure 5. Examples of fractal patterns in nature. Taken from (Joye and van den Berg, 2018)

Due to the self-similarity of patterns at different scales, natural scenes would contain more redundant information than urban scenes, making them easier to process (Joye et al., 2016). The importance of fractal dimension (*D*) in aesthetic preference has been showcased in many studies (Van den Berg et al., 2016; Clifford et al., 2005; Hagerhall et al., 2004, 2008, 2015; Joye et al., 2016; Patuano, 2018; Taylor et al., 2011). Research has attempted to find a preferred *D* value range, although differences in operationalization and stimulus sets, like computer-generated fractals versus natural fractals, yield inconsistent results (for a discussion, see Hagerhall et al., 2004). As such, it has been posited that different fractal sources lead to different preferred *D* values. Aks and Sprott (1996) and Hagerhall (2004, 2008) found a preferred *D* value of 1.3 using stimulus sets comprised of natural landscapes. Spehar and colleagues

(2003) found that a *D* value of 1.3 to 1.5 was preferred irrespective of the fractal origin (natural, computer-generated, or paintings). Similarly, using computer-generated fractals, Abraham and colleagues (2003) found that preference followed an inverted U-shape in relation to *D,* with the values ranging from 1.4 to 1.6 receiving the highest preference ratings. The difference in fractal sources seems to be encompassed in a recent paradigm which dichotomizes 'statistical' and 'exact' fractals. Statistical fractals refer to those observed in nature, and look *similar* at different scales, whereas exact fractals are computer-generated and look *identical* at different scales (see Figure 6). In an EEG study, Hagerhall and colleagues (2015) found that frontal alpha activity was highest for *D* values of 1.3 and increased with randomness, which is a characteristic of natural fractals. Frontal alpha activity is associated with a wakefully relaxed state and internalized attention, and therefore this study links the restorativeness of nature to low-to-mid range *D* values. Joye (2007) corroborated this argument: "if fractal characteristics underlie aesthetic responses to natural settings [...] and if these responses are maximal for an intermediate fractal dimension, then it could well be that this range of values will also have the highest restoration potential."

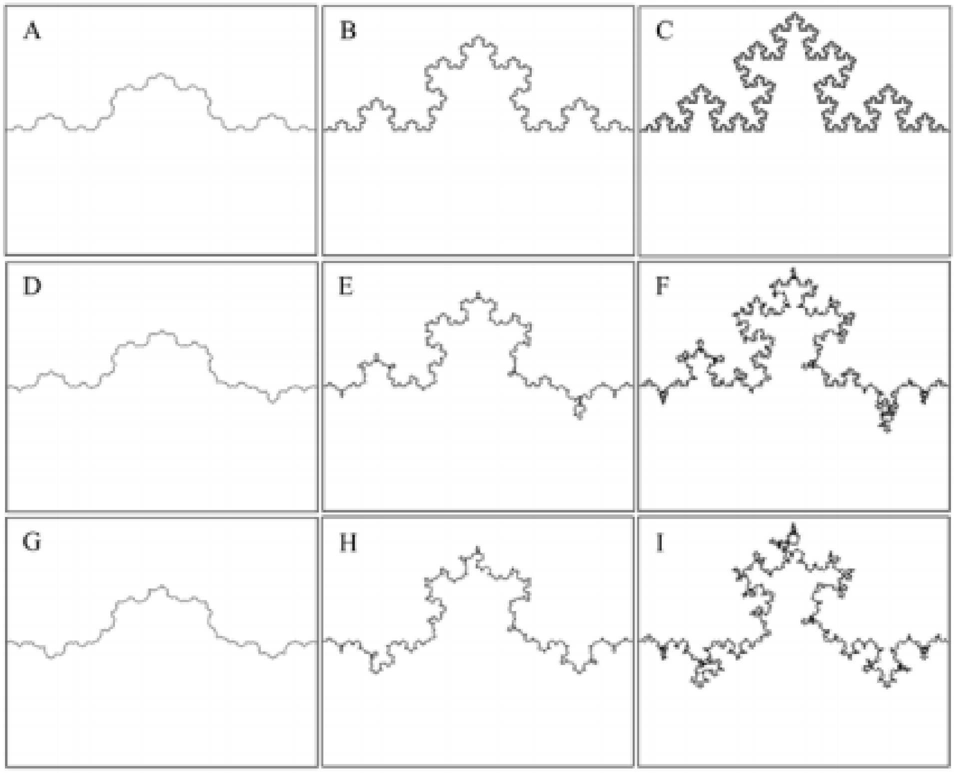

Figure 6. Exact and statistical fractals. The stimuli used in Hagerhall et al., 2015: in each column, randomness increases from top to bottom, representing a gradual increase from exact to statistical fractals; in each row, *D* value increases from left to right (1.1, 1.3, and 1.5), thereby increasing complexity.

Other researchers have found that preferred fractal dimension varies with personality (creativity: Richards, 2001) or cross-culturally (Patuano, 2018). For example, Patuano (2018) found that preferred *D* value varied between French and British participants, and as a function of childhood environment (urban, rural, peri-urban). However, the study yielded no evidence in favor of a preferred *D* value between 1.3 and 1.5.

Although it is plausible that low-to-mid fractal dimensions are preferred (over high fractal dimension or no fractal dimension), this does not comprehensively explain the aesthetic preference for nature nor its restorative properties, as it leaves out visual properties such as color, other modalities such as sound, but also any semantic feature that an image or landscape may hold. In this sense, perceptual fluency offers a narrow explanation for the bottom-up (stimulus-driven) preference for natural shapes over built ones, and this would apply to our preference for nature because nature is overwhelmingly fractal.

A recently proposed framework elaborates on the idea of conditioning to explain restoration (Egner et al., 2020). In the Conditioned Restoration Theory (CRT), the process of restoration in any environment is developed throughout four steps: Unconditioned restoration, Restorative conditioning, Conditioned restoration, and Stimulus generalization. During the first phase, restoration is unconditioned to an environment – restoration occurs as the outcome of an activity, usually relaxation or leisure activities, and not as the direct product of the environment. As the activity and the environment are paired, the restorative experience gradually becomes conditioned to the environment in which it takes place. With time, the environment is conditioned enough to the experience of restoration that this can occur in the absence of the initial restorative activity, i.e. simply by being exposed to the environment. Finally, when the environment is so strongly coupled to the restorative experience, associated environmental cues (e.g. a picture of the environment) may have the ability to trigger a restorative experience. The generalization of stimulus response is evident through, for example, VR studies that elicit similar response patterns to viewing actual stimuli, and more generally, the similar response between real and simulated nature (Browning 2019, Browning 2020), or fragments of nature such as indoor plants (Bringslimark et al., 2009). In sum, this framework posits that nature's restorativeness may be due to the kind of activities we carry out when we visit nature, i.e. leisure, relaxation, etc. According to the authors, "nature is more restorative because it is more detached from everyday life than almost any other environment" (Egner et al., 2020). This is in line with the finding that forestry professionals experience less restoration when in nature (von Lindern et al., 2013) – since this is their workplace, perhaps a different kind of conditioning would have been established. Likewise, preferred fractal dimensions vary cross-culturally (Patuano, 2018). As this is difficult to explain from an innate perspective, it could be the case that individuals from different cultures are conditioned to prefer different fractal dimension values. Fundamentally, CRT explains restoration through the lens of SRT: our affective responses to the (conditioned) environment foster physiological well-being (e.g. reduction of stress). However, CRT differs from SRT in that the stress-reducing responses to natural environments are neither automatic nor universal. In CRT, these environments and responses are selected through the mechanism of evaluative conditioning rather than innate evolutionary tendencies. According to both CRT and SRT, attention restoration is seen as a by-product of stress reduction. CRT can be generalized to explain many different restorative and non-restorative experiences. For example, in a study on restoration in museums, it was found that 'experienced' museum-goers were more likely to experience restoration than 'novices' (Kaplan et al., 1993). This could be explained by the fact that the novices had not frequented this environment enough to condition it with a restorative response. On the other hand, negative stimuli or activities can also be conditioned. For example, "on a subway, one can repeatedly experience being in a rush, which causes stress. The negative emotions produced by this will condition with the subway itself and be re-experienced when exposed to subways" (Egner et al., 2020).

As such, CRT potentially incorporates the conditioning between any stimulus and any valence of response (i.e. stressful, restorative). It attempts to explain restoration and stress through the lens of SRT and evaluative conditioning. However, the latter proves to be somewhat of a limitation to the theory: evaluative conditioning has been mostly showcased through laboratory experiments, and thus lacks a certain degree of ecological validity. Another limitation is the evidence for innate preferences. For example, conditioning a fear of snakes is easier than a fear of guns (Fox et al., 2007), and studies have found a cross-cultural preference for wide canopy trees (Lohr and Pearson-Mims, 2006). These go against the sole explanation of conditioning. Nonetheless, the authors argue that innate predispositions and conditioning can coexist. Although this theory is still in its infancy, this could form an alternative explanation for restoration that would rely less on difficultly provable evolutionary claims and encompass more of the various modalities that interplay in our preference for nature.

In conclusion, two approaches attempt to explain our preference for natural environments. The first one offers a bottom-up account, which is stimulus-driven, and often relies on evolutionary theories to explain why we prefer different environmental stimuli. This encompasses theories such as the biophilia hypothesis (humans have an innate urge to connect with nature), stress reduction theory (positive interactions with nature over evolution have shaped a stress-reducing response to it), the savannah hypothesis and prospect-refuge theory (our environment of evolutionary adaptedness has shaped our sense of preference) as well as perceptual fluency (nature has more redundant information which is easier to process). In these theories, people exhibit genetically hardwired responses to natural stimuli. Such frameworks are used to study why natural environments are more restorative than their counterparts, particularly by looking into how differences in stimulus features drive psychophysiological responses and restoration (Haga et al., 2016).

The second approach is a top-down account, and is rather meaning-driven, asserting that our preferences are more shaped by learned associations. This is evidenced by the studies showcasing sound associations (the same sound is presented to two groups, but the meaning of the sound is manipulated; Haga et al., 2016; Van Hedger et al., 2019a), the importance of semantics in visual studies (Ibarra et al., 2017; Kotabe et al., 2017), restoration in places other than nature (museums: Kaplan et al., 1993; urban environments: Staats et al., 2016; religious buildings: Herzog et al., 2010; Ouellette et al., 2005), as well as non-restorative experiences for people who work in nature (Collado et al., 2015; Hoyle et al., 2017; von Lindern et al., 2013). It is further evidenced in the way knowledge-meaning systems may modulate the perception of a stimulus. For example, people prefer the taste of a cup of coffee when the cup is labelled eco-friendly rather than with a generic label, even when it is the same coffee inside (Sörqvist et al., 2013), and abstract art images are more preferred when the observers think they come from a museum rather than being computer generated (Kirk et al., 2009). The importance of meaning is also evidenced more generally by the fact that different stimuli can give rise to similar restorative responses. For example, natural sounds are more restorative than urban sounds or noise (Benfield et al., 2014; Jahncke et al., 2015), and natural scenes are more restorative than built environments (Berto, 2005; Ulrich et al., 1991) – because similar restoration occurs using different stimuli (visual and auditory), this suggests that it is not the stimulus features in themselves that drive the restorative response but rather the meaning associated with them, namely the positive association with nature (Haga et al., 2016). Thus, although stimulus features are undeniably important – as evidenced by our preference for fractal over non-fractal shapes – they do not fully explain why some stimuli are more restorative than others. Cognitive components must also be taken into account. Our aesthetic preference for natural environments thus stems from an interplay between preferred stimulus features and associated meanings.

This suggests that further research should perhaps focus less on the search for the 'holy grail' of natural stimuli that would explain the restorative properties of nature, justified speculatively with claims about the wants and desires of our Hominid ancestry. Rather, a more pertinent line would be to understand how our increasing disconnection from nature may potentially foster a craving for it, or how its destruction on a global scale may lead to an urge to preserve it - even if that means pretending that coffee from an eco-friendly cup also tastes better. What meaning do we associate with nature? As pointed out by Schertz and colleagues (2018), thought topics related to "Spirituality and life journey" were highest correlated with walking in a park. Perhaps an environment of concrete roads and buildings is less attractive than a park because of the low NSED and fractal dimension, but perhaps it is also simply because fewer restorative activities or thought topics are associated with a concrete road: a concrete road fails to suggest the idea of taking a nap, reading a good book, or sharing a picnic with friends or family. Further, interindividual differences also seem to play a major role in restoration – if 'city people' can feel restored in urban environments, and 'museum people' can feel restored in museums, perhaps 'car people' could feel restored by driving on a long stretch of concrete road by letting their minds drift off into introspective thoughts and soft fascination - although I personally do not suggest trying this. Indeed, it does seem that beauty is in the eye of the beholder, which is quite contradictory to the mainstream line of research that seeks to prove the universality of nature's restorativeness. Instead, it seems as though individuals find restoration through personal meaning – at least in part, and at most completely. If nature means leisure, relaxation, pleasant fragrances, beautiful fractals, vivid colors, time spent with family, time spent away from traffic or work, or any other possible positive association one could conjure, then it would indeed appear to many of us like a good candidate for restoration. On the other hand, if urban environments mean noise, pollution, traffic, unappealing buildings, social comparison and expectancy, or any other negative association, then it seems unsurprising to seldomly experience restoration there. However, meaning is subjective, malleable, and nature could also mean work, thorns, dirt, a bad childhood experience, rain, or likewise an urban environment could mean friends, activities, beautiful buildings, opportunity, and thus the restorative outcomes could be reversed. Still, because the data in the vast majority of studies suggest that the former set of associations are most widespread, future research should attempt to elucidate why we overwhelmingly prefer associations with nature and naturalness to their urban counterparts, and of what precisely these associations consist. In line with this, the pertinence of genetic and epigenetic factors should be reevaluated compared to cognitive factors related to environmental sensitivity, disconnection, and personal meaning.

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