Why we love nature

Essay on the human experience of ‘nature’ and the related cognitive and neurobiological mechanisms affecting our health and well-being

Essay

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Abstract

The increasing urbanization of our environment results in less opportunities for us to engage with and experience nature. More than half of the world's population is currently living in cities, which seems to correlate with an increase in multifactorial, lifestyle-driven non-communicable diseases that are responsible for 38 million deaths annually. An extensive amount of research found that experiencing nature is beneficial for our health and well-being. However, the mechanistic pathways behind these effects are not fully understood yet. According to the Biophilia Hypothesis we have an evolutionary and ontogenetic tendency to affiliate with nature, based on weak innate learning rules, that causes us to be fascinated by and emotionally connect to nature. Fascination triggered by the properties of natural elements, such as fractals, allows our directed attention to rest which relates to a reduction of our stress response (Attention Restoration Theory, top-down perspective). Moreover, our initial emotional response to nature mediated by the vmPFC is positive, also leading to a reduction of our stress response (Stress Reduction Theory, bottom-up perspective). Next to the direct effects of the experience of nature on our stress response, it is becoming increasingly clear that health at all levels: person, place and planet, is interdependent. A conceptual model called the Lovebug Effect explains how human-microbe coevolution can lead to human-microbiota feedback mechanisms that increase our biophilic drive and positive response to nature in terms of health and well-being. The variety of theories and their mechanisms described in this essay demonstrates that experiencing nature positively impacts health and well-being via different pathways. A holistic approach to our relation with nature is necessary to elucidate cross-talks between different systems and to foster opportunities for interventions to multifactorial health problems related to urbanization.

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1. Introduction

We have an intuitively idea that nature is good for us, which stems far back. For example, Frederick Law Olmsted, who founded the field of landscape architecture in America and designed and planned hundreds of landscape commissions across the country around 1858-1893, contended that for individuals experiencing stress, viewing nature 'employs the mind without fatigue and yet exercises it; tranquilizes it and yet enlivens it; and thus, through the influence of the mind over the body, gives the effect of refreshing rest and reinvigoration to the whole system' (*About the Olmsted Legacy - National Association for Olmsted Parks*, n.d.; Kaplan, 1995). This tendency of us to believe nature is beneficial for our health is now recently backed up with more and more research. A great amount of studies is showing that time spent in nature correlates to positive health effects. As an example, distraction therapy with nature sights and sounds reduces pain during operations (Diette et al., 2003), or enhanced post-operative recovery (Ulrich, 1984). Additionally, spending time in nature can improve working memory capacity (Berman et al., 2008), restore directed attention (Berto, 2014), as well as reduce negative emotions and stress (Oh et al., 2017; Park et al., 2007; Tost et al., 2019). However, our world has quite recently gone through a major change in which there is an increasing urbanization of our environment which resulted in more than half of the world's population is currently living in cities, which will only expand to 7 out of 10 people living in cities by 2050 (*Urban Development*, n.d.). This change means that the availability of spending time in nature will be less and less for most people, which can give rise to feelings of concern for our health. The growing attention for research on the relationship of nature and health reflects our concerns of diminishing possibilities for human contact with nature, due to urbanization, environmental degradation and lifestyle changes (Hartig et al., 2014). However, we know that humans are relatively flexible and can survive in a broad range of environments, demonstrated by our abilities to survive and live a healthy life in the Artic or in the completely different environment of the African savanna (Laland & Brown, 2006). This gives hope that we are able to adapt well to the urbanization of our environment. And indeed, urbanization has many advantages, like an enhanced access to important opportunities of medical, recreational and cultural services. Nevertheless urban habitats seem to be a bit harder for us to adapt to, elucidated by the many studies exposing the negative health consequences of living in an urban compared to a rural environment. As an example, living in cities is connected with greater prevalence of mental diseases, with rates as much as 30% higher for conditions such as mood disorders (Peen et al., 2007, 2010). Additionally, urban upbringing seems to be the most influential environmental factor for the development of schizophrenia, accounting also for more than 30% of the schizophrenia incidence (Krabbendam, 2005; Os, 2004). What features of this urban environment are at the root cause of these enhanced risk for metal diseases are yet to be determined. However, research has identified several factors at the level of urban neighbourhoods (macro-level) and within individuals (micro-level) that seem to shape the neurobiological mechanisms which are determining our mental health. Continuing this line of research is important as understanding what exactly causes the beneficial effect of nature and the detrimental effects of urban environments on our health can help us to make better designs and approaches on different levels for dense urban settings to overcome our adaptive lag to this relatively new urban environment and improve global health in the future. This fits well with the hypothesis of the study of Laland & Brown (2006), which states that humans construct their world largely to suit themselves and frequently buffer an adaptive lag through cultural niche construction. Additionally, understanding the importance of the natural environment for our health can also increase our relationship with nature for the better and our feelings of necessity to deal with the global climate crisis we have now (Nisbet & Zelenski, 2011).

To explore the beneficial effects of being in nature, we must first define what nature exactly is. Is it an area which humans led untouched so that plants and animals established their own biome. Or could it

also be a park with trees placed and chopped in a certain aesthetically pleasing way? Nature can be defined objectively by referring to the physical characteristics and processes of nonhuman origin that people ordinarily can perceive. This includes the “living nature” of flora and fauna, as well as still and flowing water, qualities of air and weather, and the landscapes that comprise these and show the influence of geological processes. In this case the terms “nature” and “natural environment”, which refer to a setting with little to no noticeable signs of human presence or interference, overlap significantly (Hartig et al., 2014). However, most research on this subject refers to nature as places situated in built environments too, such as indoor plants and street trees, or allotment (or community) gardens and urban parks, that comprise natural features and/or appear natural and provide opportunities to engage with and follow natural processes, even though they are usually created, built, controlled, and maintained. According to research a person can also experience nature when viewing natural elements or landscapes from a building or vehicle, in pictures and movies, or in virtual reality environments (Hartig et al., 2014). The way we experience nature can be very subjectively, which makes it effective as a social construction.

This essay will focus on the research question: ‘What cognitive and neurobiological mechanisms that affect our health and well-being are related to the experience of nature?’. According to the World Health Organization (WHO), health and well-being is understood not only as the absence of disease, but as a state of complete, physical, mental and social wellbeing (World Health Organization, 2020). Therefore, the arguments in this essay will not be oriented towards the causes of disease, but rather toward factors that produce, secure, and promote health in a holistic manner (Herchet et al., 2022). Three of the most important theories about the impact of nature on our cognitive and mental health and their evidence will be highlighted: The Biophilia Hypothesis, the Stress Reduction Theory and the Attention Restorative Theory.

2. Biophilia Hypothesis

Why do we, humans in general, love nature so much? A nice overarching theory that tries to explain our innate tendency to affiliate with the natural world is the Biophilia Hypothesis, first described by Wilson in 1984 (Wilson, 1984). Biophilia, where ‘bio’ is ‘life’ and ‘philia’ is ‘love’ in ancient Greek, means love of live. It states that our love for nature is mediated by a number of evolved survival-based biopsychological responses to environmental stimuli, such as the drive to find nutrients and materials for shelter (Robinson & Breed, 2020). This drive is at the root of our affiliation with nature and the reason we attach values to nature ranging from ecological-scientific to aesthetic values. In total, research has defined nine different values that fall under Biophilia (Delavari-Edalat & Abdi, 2010). Ecological-scientific values support our desirability to learn about nature to get life’s physical and mental requirements which is important for evolutionary fitness, while aesthetic values stimulate the way we seek beauty in nature which provides for sensory pleasure and has associated benefits for our well-being. Utilitarian values define the value we attach to natural materials and the physical benefits derived from nature. Naturalistic values can be regarded as the enjoyment caused by direct contact with nature, which entails awe and fascination brought on by a close encounter with the diversity and complexity of nature. Symbolic values define the use of nature as symbols, which may have had an great impact on how human language evolved, as well as the complexity and communication that were promoted by this "symbolic" approach. Humanistic values, reflect feelings of deep emotional attachment to individual elements of nature and the feeling of saving it, while moralistic values emphasise feelings of ethical responsibility and what is right and wrong to conduct to the natural world. And at last, dominionistic values include the desire to get control over the natural world, where

negativistic values highlight the feelings of fear and aversion over the natural world (Delavari-Edalat & Abdi, 2010).

As is described in the article of Barbiero and Berto (2021), there are two different perspectives to take on the Biophilia hypothesis: a phylogenetic perspective, explained by Wilson (1984) or the predominanty ontogenetice perspective, described in the many books written by Fromm (Fromm, 1955, 1956, 1963, 1964, 1966, 1976, 1994). The phylogenetic perspective is much more operational as it states that Biophilia are traits evolved under evolutionary pressure that allow us to develop a mental link with nature. This metal link with nature is at the basis for the nine values of Biophilia and thus involves more then only the simple issues of material and physical sustenance. The human craving for aesthetic, intellectual, cognitive and even spiritual meaning and satisfaction is included too (Robinson & Breed, 2020). According to the phylogenetic perspective this craving is satisfied by nature via two fundamental constructs: 'fascination' and 'affiliation'. With fascination for nature it is meant that people respond with involuntary attention to natural elements and that nature thus represents a fascinating stimulus which attracts our attention without effort. It is thought that our directed attention can rest and be restored from mental fatigue during the time nature attracts our involuntary attention (Barbiero & Berto, 2021). The latter hypothesis is a key concept in the Attention Restorative Theory of nature, which will be elaborated on later in this essay.

The second fundamental construct of the phylogenetic perspective of Biophilia is 'affiliation'. Our affiliation with nature represents an emotional bond with specific forms of life in certain circumstances and resides in our capacity to feel empathy for other creatures and acknowledge and act to their concerns as if it were our own (Barbiero & Berto, 2021). Usually empathy feelings only develop between human beings, however we also seem to have a capacity to feel empathy for natural elements, which is interesting as this can be a mediator for our affiliation with Nature (Di Fabio & Kenny, 2021). According to Barbiero and Berto (2021), becoming emotionally affiliated with the environment has an evolutionary advantage and as suggested by the Stress Recovery Theory of nature (Ulrich et al., 1991), empathic contact with nature can lead to stress reduction, which will also be elaborated later in this essay. However, our capacity to affiliate with nature does not only lead to positive feelings and empathy. It also gives rise to feelings all over the emotional spectrum, such as attraction to aversion, awe to indifference and peacefulness to fear-driven anxiety. With this in mind, it is important to also include biophobia in the framework of the Biophilia hypothesis, as it represents an intrinsic and complementary part of the same overarching evolutionary framework. These fear responses to nature are believed to have evolved in an environment where humans faced a high risk of predation and/or toxicity from phyto- or zootoxins (Robinson & Breed, 2020).

Additionally to the phylogenetic perspective of Biophilia, it is hypothesized that Biophilia is not a single instinct, but a complex of learning rules. The article of Barbiero and Berto (2021) emphasizes that Biophilia is innate but not instinctive in the sense that it does not give rise to rigid and deterministically fixed behaviour, but that we have an innate predisposition to learn from and interact with nature instead which is thought to be evolutionary advantageous. Biophilia is therefore a basic relatively stable personality trait, characterized by weak learning rules, leaving more than enough freedom to the individual. These learning rules support the argument for the ontogenetic perspective, first described by Fromm, as they allow for the opportunity for environmental conditions (natural and social factors) to have an influence on the growth and development of Biophilia. Barbiero and Berto (2021) defined these learning rules as already present since childhood, as having counterparts in animals and being determined by biological mechanisms that are innate, and as being vulnerable to chance caused by maturation and specific interactions of the genotype and environment. As an example, people with high affiliation with nature, seem to prefer natural environments that are higher, while people prefer

more domestic natural environments when they have a lower affiliation (Davis & Gatersleben, 2013; Løvoll et al., 2020). In addition to the learning rules that are at the basis of this affiliation, Fromm describes that the three conditions are important for the development of Biophilia, namely: security, justice and freedom. Nevertheless, the nature stimuli that are useful for developing Biophilia have been reduced in our recent history because of urbanization which leaves less opportunity for contact with nature. To experience the beneficial effects of nature on health and well-being, it is therefore important to immerse oneself with nature from a young age, to develop this Biophilia.

3. Attention Restorative Theory

According to the Attention Restorative Theory of nature, nature has beneficial effects on our health because it allows for the restoration of our directed attention. The article of Kaplan (1995) nicely captures the idea of the Attention Restorative Theory of nature. It states that there are two forms of attention: involuntary attention and direct attention. Both types of attention are being similar in being inhibitory and having their effect through suppression of competing activity. However, they differ in the amount of effort they take to function. As the name might suggests does involuntary attention not require effort, while in the case of directed attention, distractions are controlled by the use of inhibition associated with the prefrontal cortex. This leaves the latter form of attention susceptible to fatiguing when used continuously. (Kaplan, 1995; Rothbart & Posner, 1985). Our directed attention is an important part for our executive functioning. It adapts our behaviour better to a situation and prevents us from being impulsive and taking unnecessary risks or acting impatiently and hasty. From an evolutionary standpoint, it is strange that a mechanism so closely involved with human effectiveness is prone to fatigue. However, according to Kaplan (1995) it actually makes sense that we cannot pay attention to one particular thing for a long period of time. Being vigilant and aware of one's surroundings may have been far more essential than the ability to concentrate for long periods of time, as in this case one would be vulnerable to surprises. Furthermore, much of what was essential during the evolution of humankind: danger, water, forest environment, blood, and so on, is already fascinating and thus does not require focused attention. The issue of directed attention fatigue may be of recent origin: because of urbanization and cultural complexity humans in modern times must put more effort to do the essential while avoiding distraction from the interesting (Kaplan, 1995). Directed attention is thus important for human functioning, but it can be easily fatigued hypothetically for evolutionary reasons. How exactly can we recover from directed fatigue? Sleep might be an efficient way, however, according to Kaplan (1995) this is insufficient. He states that one must switch from directed attention to involuntary attention so that directed attention is able to rest. Nature does meet all of the four requirements proposed by Kaplan (1995) that are necessary for a restorative environment in which our directed attention is able to rest: it holds soft fascinations, it can provide for the feeling of being away (at least in principle), it has environmental extent, it can serve compatibility with our purposes and inclinations. And indeed, many studies show the relation between restorative experiences and information-processing effectiveness (Cimprich, 1992, 1993; Cornwell, 1976; Hartig et al., 1991; Orbach et al., 1963). Additionally, there are many studies showing the co-occurrence of stress and performance decline.

This relationship between stress and performance decline might intuitively seem to be logical. Nevertheless, Kaplan (1995) stresses that interpretation of the results regarding this issue may be essential to understand the causal reasons to why we regard spending time in nature as such a positive and restorative experience. According to Kaplan (1995) three patterns can lead to the coexistence of resource deficiencies (lack of direct attention) and the stress response. In the first pattern, fatiguing of direct attention is a precursor of the stress response. For the second pattern, the stress response is

not resource-based, but for example caused by discomfort and injury, which then leads to resource shortage. And at last, both stress and resource depletion can occur simultaneously induced by many circumstances and averse stimuli.

4. Stress Reduction Theory

The next theory that will be highlighted in this essay is the Stress Reduction Theory proposed by Ulrich (Ulrich et al., 1991). This theory tries to explain the effects of nature seen on stress reduction and fits therefor well in the framework of Biophilia as this also argues for the stress reducing properties of nature. Several approaches to the Stress Reduction Theory focus on arousal. These approaches state that nature has low levels of arousal and complexity, which makes it an ideal setting to recuperate after being in an environment where there is excessive arousal and complexity leading to stress, for example in cities. It adheres to the idea that stress recovery can occur best in environments with low complexity and arousal properties. The study of O'leary shows that indeed preferred levels of complexity decline when individuals are stressed or anxious (O'leary, 1965). Other approaches to the Stress Reduction focus on overload by stating that complexity and other arousal stimuli ask for high processing demands, which impedes or delays stress recovery. Urban environments issue a high degree of complexity, intensity and other arousal increasing elements, such as heavy traffic or places with a lot of people, which does not promote stress recovery, while the opposite is true for nature. Both perspectives, the arousal approaches and the overload approaches have in common that urban environments are thought to be perceived as complex and arousal inducing, which can lead to more stress, while nature has restorative influences on stress.

From an evolutionary point of view it makes sense that natural content is processed relative easily and efficiently, and we are prepared to acquire quick restorative responses in these settings, as the systems in our brain that are related to this processing evolved in natural environments. Since sympathetic and other physiological mobilization over a prolonged period of time is exhausting and linked to chronic endocrine and cardiovascular responses negatively affecting heath, the ability to rapidly attenuation our stress responses and foster a recharge of physical energy after a threatening encounter has a major advantages. Many studies have indeed shown adaptive physical responses such as heart deceleration to unthreatening natural settings (Laumann et al., 2003). According to the Stress Reduction Theory of Ulrich, the restorative effects of nature are rooted for a part in positive changes in emotional states accompanied by attention. Our positive initial affective response to nature lead to positive feelings and a prolonged attention or intake. However, some natural elements can have a strong involuntary attention or fascination but are actually anything but restorative. For example snakes, spiders or heights are things that many people respond to with negatively-toned emotions and autonomic activation. Therefore, in addition to attention or fascination, the role of positive feelings are important to explain the mechanisms of the Stress Reduction Theory.

5. Neurobiological Mechanisms

There are many fields of research that contribute to the understanding of the mechanisms of these three theories regarding nature's beneficial effect on health and well-being. Ranging for example from air quality, physical activity to social cohesion (Hartig et al., 2014). This essay will focus on the role of visual processing of nature, emotionally connecting to nature and our microbiome and nature.

5.1 Visual processing

An interesting topic that can help to explain why natural elements have the ability to held our involuntary attention and with that restore our directed attention and/or reduce our stress response, is the topic of fractals. Fractals are patterns in our visual field that recur at progressively finer scales, resulting in shapes with rich visual complexity (Brielmann et al., 2022). Clouds, forests, mountains, cauliflowers and fern leaves are typical examples of fractals. The fractal dimension D is the parameter that defines the fractal scaling connection between patterns seen at various magnifications. Interestingly, visual appeal peaks for mid-range D values of 1.3 to 1.5 (Fig. 1) which happen to be most prevalent in nature and art (Spehar et al., 2003) and is "universal" as gender and cultural background had no significant influence on this D preference (Abraham et al., 2003). The study of Taylor (2006) shows that looking at pictures of nature dampens the physiological stress response. This dampening was higher when looking at a nature picture that had a D value which falls into the aesthetically pleasing range compared to picture that falls outside this range (Taylor, 2006).

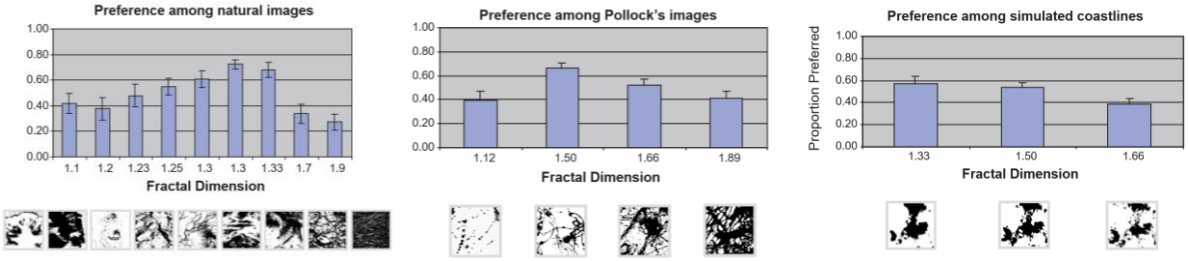

Fig. 1. **Aesthetic preference for fractal images of different origin:** average proportion by which the image was preferred among others as a function of fractal dimension for natural images (left panel); simulated coastlines (middle panel); and cropped images of Pollock's paintings (right panel). Derived from: (Spehar et al., 2003)

It is proposed that scenic information is processed in the visual cortex via a network of virtual "pathways" that have evolved to directly match the fractal scales that dominate the environment (Field & Brady, 1997). Naturally structured environments are easy for us to process and produce less strain on our perceptual and cognitive system. Interestingly, our brain can process a classical/traditional building as easily as a tree, because of their common fractal and other symmetries (Buras, 2019). This could be taken into account when designing cities. Next to the virtual pathways in our visual cortex, it has also been suggested that the brain calls on fractal memories as part of visual processing, by integrating current perceptual information with fractal images stored in our long term memory (Mikiten et al., 2000). But not only our brain is developed in a way to process nature's fractals easily. The way we scan our environment with our eyes has a fractal character too. Since only the fovea in our eyes can gather sharp and fully coloured visual information, moving our gaze in a fractal manner is necessary to confirm the scene's fractality. We move our eyes with voluntary, quick movements called saccades, which trace out fractal search patterns, regardless of the geometry or the image. This fractal trajectory of eye-scanning movements can be traced back to mammal foraging behavior, as this is done in the same movements (Fairbanks & Taylor, 2010). At last, our pupil dilation also varies in a fractal way when the eye moves over fractal images, suggesting further refinements in the search mechanism (Moon et al., 2014).

5.2 Emotional connection

Our positive initial affective response to nature, explained by the theory of Biophilia, lead to positive feelings and a prolonged attention or intake. Nature can draw involuntary attention or fascinate people, which is mediated with positive feelings. These positive feelings play a big role in stress reduction. It has been shown that both physiological effects and cognitive residues of stressors are reduced by positive emotions (Falkenstern et al., 2009; Fredrickson et al., 2000; Fredrickson & Levenson, 1998).

One of the neurotransmitters which is extensively researched in relation to positive emotions is dopamine. Dopamine is a big player in reward-related processes involving hedonic experiences of pleasure, motivation to seek reward and reward-based learning (Berridge & Kringelbach, 2008). Dopamine has an optimal level when mediating the effect of positive emotions following an inverted U-curve (Yin, 2019). Many of the effects of positive emotions on behaviour and cognition are mediated by the dopamine system when dopamine is at its optimal level (Yin, 2019). Such positive effects are for example creative problem solving and improving cognitive flexibility, associated with increased dopamine levels in the frontal cortex. In addition to dopamine, the study of Koepp and colleagues (2009) show that endogenous opioids are involved in the regulation of positive emotions and their beneficial effects on health (Koepp et al., 2009).

But what exactly triggers these positive emotions when experiencing nature in the first place? The study of Yang and colleagues (2018) found that the ventromedial prefrontal cortex (vmPFC) plays an important role in regulating positive emotions during and after a stressor, by signalling to other brain areas leading to stress recovery. In the case of a stressor, the amygdala and the ventral striatum together with areas such as the brainstem, temporal lobe systems and prefrontal control centres, provide affective and motivational information about this stressor and current behavioural goals to the vmPFC (Ochsner et al., 2012). The vmPFC integrates this information in a context and goal dependent manner and then provides positive emotion signals, which in turn predicts less negative emotions (Winecoff et al., 2013). The study of Sudimac and colleagues (2022) show that amygdala activation decreases after a walk in nature, whereas it remains stable after a walk in an urban environment (Sudimac et al., 2022). In this case, the vmPFC thus receives different information which could possibly lead to a more positive emotional signal. A study that demonstrates the release of positive emotions after evaluation in goal dependent manner is the study of Hare and colleagues (2009). They demonstrate activation of the vmPFC when looking at an image of healthy but not tasty food depends on whether one has the goal to eat healthily (Hare et al., 2009). This suggests that the way we think about something influences activation of the vmPFC facilitating a positive emotional reaction. Indeed the study of Yang et al. (2018) showed that 'decentering', which is the meta-cognitive detachment of oneself from one's feelings, lead to the activation of the vmPFC and the following positive emotions during stress recovery. Positive emotions have been shown to dampen cortisol and reduce negative emotions during stress recovery (Speer & Delgado, 2017) (Fig. 2). These findings support the argument mentioned earlier in this essay, that arousal or overload theories regarding the Stress Reduction Theories are insufficient to explain nature's restorative effects on stress. The importance of our emotional response to nature must not be forgotten. If our emotional response to nature is negative, for example in the case of being afraid of snakes or heights, the resulting emotional, cognitive and/or physiological response will most likely not be restorative, if not distressing, regardless whether the response involves involuntary attention or fascination.

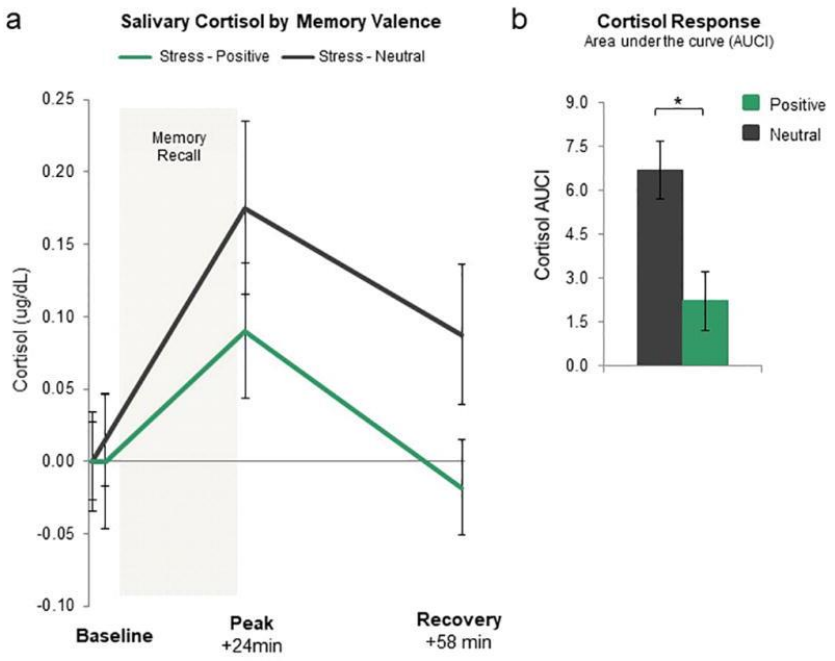

Fig. 2. **Neuroendocrine Responses to Acute Stress in fMRI:**
Participants were exposed to an acute stressor or control task prior to autobiographical memory recollection. Importantly, half of the sample reminisced about positive memories, whereas the other half reminisced about neutral memories. Stress participants underwent the Socially Evaluative Cold Pressor task (SECPT; immersed hand in ice cold water under social threat), which reliably activates the HPA axis, producing elevated cortisol levels about 15 min after the stressor. To assess physiological changes to stress over time, salivary cortisol was collected.
a) Baseline-corrected salivary cortisol measured in micrograms per deciliter at four time points across the experiment including immediately before the SECPT/control procedure (baseline), as well as 2 min, 24 min (peak) and 58 min (recovery) after the SECPT/control procedure for all participants (N = 43). b) Cortisol response in terms of area under the curve with respect to increases from baseline (AUCI). Stress-Neutral group has a significantly larger AUCI cortisol response than the Stress-Positive group. *p < .05; error bars denote SEM. Derived from: (Speer & Delgado, 2017).

5.3 The Lovebug Effect

An interesting framework that contributes to the understanding of the mechanisms behind the Biophilia Theory is the Lovebug Effect. The study of Robinson & Breed (2020) presents the Lovebug Effect as a conceptual model for microbially-influenced nature affinity. In addition to the neurobiological and cognitive explanations of the Biophilia Theory that are based on psychological traits, they propose that there could be external forces, such as the microbiome, which influence our biophilic drive. Health and well-being, physically and psychologically rely for a part on microbial communities which are strongly influenced by environmental factors such as food and interactions with the surrounding environment. For some of these environmental factors we cannot control, however, for some other factors we do play a considerable role in controlling/selecting via horizontal microbial transmission and thus allows us the power to shape our microbial community. Engaging with nature is therefore a way shape your microbial community and align it to the microbiota that can be found in the natural environment that we engage in. A study that supports this line of thought is the study of Sobko and colleagues (2020). They found that the gut microbiota of children was altered, especially by modulating the abundance of *Roseburia* and the fecal-serotonin level, after an intervention consisting of outdoor nature-related activities and that children were significantly more connected to nature based on the results of validated questionnaires. Additionally, there was found a reduction in the overall perceived stress, particularly in the frequency of anger among these children, which suggest a positive impact of being on nature on health and well-being regulated by microbiota-environment crosstalk (Sobko et al., 2020).

Exposure to environmental microbiota subsequently lead to colonisation of these microbiota in the host, which has a human adaptive advantage as it trains our immune system, helps us maintaining core biological functions, excludes pathogens because of competition and has also multisensorial health benefits (Robinson & Breed, 2020). Because of these adaptive advantages, there is a potential for human-microbe coevolution and/or unilateral adaptations which allows for the development of human-microbiota feedbacks. Robinson & Breed (2020) mention potential mechanisms via which human-microbiota feedbacks can lead to direct manipulation or selected behavioural traits, providing a biophilic drive towards natural environments. These mechanisms include the production of metabolites by the microbiota which can for example 'hijack' communication structures, alter levels of neurotransmitters, hormones or neuroactive molecules, or alteration of peripheral immune cells that stimulate interaction with the blood-brain barrier (Robinson & Breed, 2020).

The interactions of our microbiome with our brain are complex and the exact relations are not yet fully understood. However, they open-up a new perspective on how nature can influence our health and well-being. For example it is thought that gut microbiota composition and function affects the hypothalamic-pituitary-adrenal axis and systemic inflammation related to the stress response (Bear et al., 2021). Thus, next to the effects of nature on our stress response via the mechanisms of the Attention Restorative Theory and the Stress Reduction Theory, nature can apparently also influence our resilience to stress via microbiome-brain interactions (Fig. 3). As an example, the study of Liddicoat and colleagues (2020) showed that a reduction of anxiety-like behaviours in mice was associated with exposure to trace-levels of higher biodiversity aerobiome treatment (Liddicoat et al., 2020).

Next to the influence of microbiota on our stress response, the Lovebug Effect states that these human-microbiota feedback mechanisms affects regulatory pathways in both cognitive and affective domains that increase our biophilic drive. In complementation of this line of thought, the study of Dwivedi and colleagues (2011) found that some of the natural smells that humans enjoy (like the earthy scents of shifting seasons and musky emissions after a rainy period) are actually volatile organic compounds made by microbes (Dwivedi et al., 2011). The Lovebug Effect is therefore an interesting addition to the understanding of the mechanistic pathways of Biophilia and the effect of nature on our health and well-being.

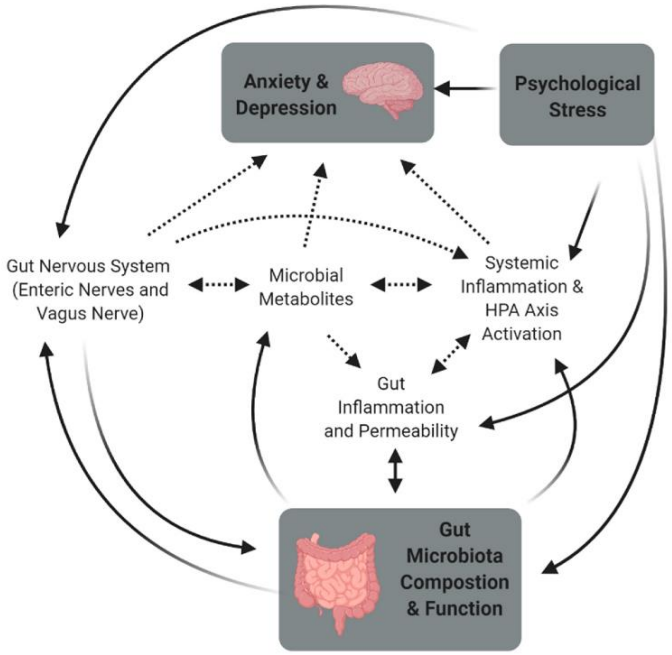

Fig. 3. **Proposed mechanisms by Bear and colleagues (2021) of the Microbiome–Gut–Brain-Axis (MGBA)** are complex and intertwined. Emerging research shows that psychological stress interacts not only directly with the brain and mood, but also with many of the MGBA mechanisms thought to contribute to changes in mood with alteration of the gut microbiota. Solid lines indicate strong evidence of an effect, and dotted lines show proposed mechanisms with limited but emerging evidence. Abbreviations: HPA; Hypothalamic-Pituitary-Adrenal. Derived from: (Bear et al., 2021)

6. Discussion

In conclusion, the human experience of nature contains several elements that have positive effect on our health and well-being. This essay focusses on three of the most important theories of the causal reasons for these positive effects of nature. Figure 4 summarizes the relation of these three theories and important factors involved. The Biophilia Hypothesis is mostly focussed on our evolutionary and ontogenetic tendency to affiliate with nature. Innate weak learning rules that have been established over the course of evolution allow us to be fascinated by nature and to emotionally connect to elements of it. However, to really experience the beneficial effects of nature on health and well-being caused by stress reduction and directed attention restoration, we need to surround ourselves with environmental conditions (natural and social factors) and opportunities that stimulate the growth and development of this fascination and affiliation to nature. The Attention Restoration Theory and the Stress Reduction Theory that are explained in this essay have a lot of similarities. The main point of the theories is that an urban environment does not allow as good as a natural environment for the fascination and affiliation necessary to prevent a stress response which can negatively impact our health and well-being in many ways. Where the Attention Restorative Theory describes a more top-down approach to the causal-effect relationship between directed attention fatigue and the stress response, argues the Stress Reduction Theory more for a bottom-up approach where our initial emotional response to nature plays a big role in the reduction of the stress response.

In the literature regarding this topic, many studies try to describe the biological mechanisms behind these theories. This essay elaborates on the neurobiological mechanisms of visual processing of natural scenes, emotionally connecting to nature and the role of our microbiome to our connection with nature. Visual processing is an interesting subject as it supports the Attention Restorative Theory by explaining how nature can attract involuntary attention so that our directed attention can rest. However, it also supports the Stress Reduction Theory, by explaining that because natural sceneries produces less strain on our perceptual and cognitive system, a stress inducing response is prevented. Furthermore, our innate tendency to affiliate with nature leads to a higher vmPFC activation which is associated with positive emotions and a recovery of the stress response. The importance of an emotional connection with nature supports the Attention Restorative Theory as this emotional connection is at the base of our affiliation to nature by which it can attract our involuntary attention. In addition, our emotional connection to nature supports the Stress Reduction Theory as our immediate emotional response can affect stress reduction. At last, the Lovebug Effect supports an alternative explanation to our affiliation with nature. According to this conceptual model human-microbiota feedback mechanisms evolved under human-microbe coevolution and/or unilateral adaptations, influence our behaviour in a way that increases our biophilic drive.

We love nature because humanity is deeply embedded within nature itself. Evolutionary and ontogenic predispositions expressed in cognitive and neurobiological mechanisms allow us to respond to nature in a way that positively affects our health and well-being (Fig. 4).

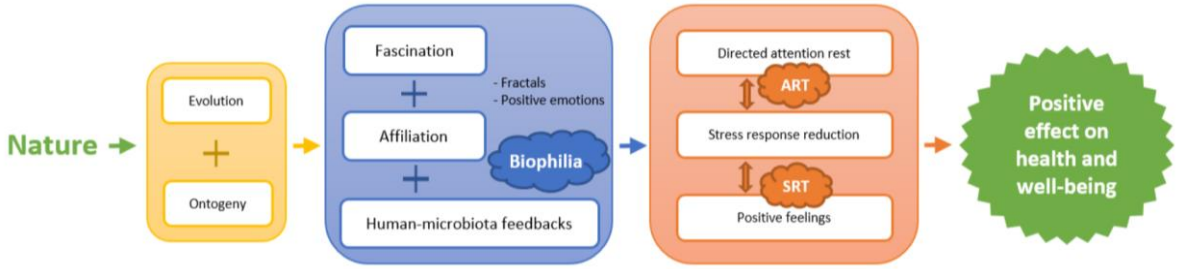

Fig. 4. **Summary main findings essay.**

7. Future perspectives

The difficulty in understanding the theories mentioned in this essay is how they relate to each other and can form one solid theory on which we can base our experiments to find out how the human experience of 'nature' is able to positively affect cognitive and neurobiological mechanisms and with that our health and well-being. The type of experiments we design are largely dependent on what theory you assume to be true. It is important to be aware of the different perspectives regarding this topic as they can also influence the way we interpret results.

Understanding the effects of experiencing nature and its mechanisms gives rise to the development of new treatments or interventions that have a goal to improve our health and well-being. One approach could be to find ways to provide people with knowledge on the importance of and actual opportunities to experience nature. Urban areas can be designed in a way that effectively increases possibilities for people to interact with natural elements and in situations where it is difficult for people to engage with nature, knowledge about the mechanisms that are behind the positive effects can help to develop fake nature experiences. Virtual reality offers for example a safe and practical solution to increase nature exposure. The study of Chan and colleagues (2021) showed that walking in a virtual forest reduced negative affect due to enhanced nature connectedness, and reduced stress measured by heart rate (Chan et al., 2021).

However, to really make a difference it is important to zoom out and look in a more holistic way at the experience of nature and our health and well-being. As is mentioned before in the introduction of this essay, our physical environment has recently gone through rapid and dramatic chances in a structurally and functional way which has an extensive impact on our experience of nature. Interestingly, this change in environment seems to correlate with an increase in multifactorial, lifestyle-driven non-communicable diseases, which are responsible for 38 million deaths annually (Allen & Feigl, 2017). Non-communicable variants of disease are epidemics of co-morbidity and are generally resistant to single-agent cures and/or biotechnological preventatives (Prescott & Logan, 2017). In addition, according to Prescott & Logan (2017), many people in westernized society are suffering even though they do not satisfy the specific criteria for a disease. Health and well-being is understood not only as the absence of disease, but as a state of complete, physical, mental and social wellbeing. Based on the results of this essay, nature seems to play an important role in maintaining our health and well-being via a variety of different pathways, of which we do not fully understand the scale and mechanisms yet. However, it is becoming increasingly clear that health at all levels – person, place, and planet – is interdependent (Prescott & Logan, 2017). To set-up interventions and to make choices on all levels that will positively impact our health and well-being, it is urgent to study our interactions with nature and their relevance to the problems of human kind from a scientific and philosophical point of view. A holistic approach to multifactorial health problems can elucidate cross-talks between different systems and foster opportunities for interventions.

8. Reference list

About the Olmsted Legacy—National Association for Olmsted Parks. (n.d.). Retrieved 28 February 2023, from https://www.olmsted.org/the-olmsted-legacy/about-the-olmsted-legacy

Abraham, F. D, Sprott, J. C., Mitina, O., Osorio, M., Dequito, E. A., & Pinili, J. M. (2003). *Judgements of time, aesthetics, and complexity as a function of the complexity of an abstract image*. http://www.blueberry-brain.org/silliman/JEM%20ms4.htm

Allen, L. N., & Feigl, A. B. (2017). What's in a name? A call to reframe non-communicable diseases. *The Lancet Global Health*, *5*(2), e129–e130. https://doi.org/10.1016/S2214-109X(17)30001-3

Barbiero, G., & Berto, R. (2021). Biophilia as Evolutionary Adaptation: An Onto- and Phylogenetic Framework for Biophilic Design. *Frontiers in Psychology*, *12*. https://www.frontiersin.org/articles/10.3389/fpsyg.2021.700709

Bear, T., Dalziel, J., Coad, J., Roy, N., Butts, C., & Gopal, P. (2021). The Microbiome-Gut-Brain Axis and Resilience to Developing Anxiety or Depression under Stress. *Microorganisms*, *9*(4), Article 4. https://doi.org/10.3390/microorganisms9040723

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The Cognitive Benefits of Interacting with Nature. *Psychological Science*, *19*(12), 1207–1212.

Berridge, K. C., & Kringelbach, M. L. (2008). Affective neuroscience of pleasure: Reward in humans and animals. *Psychopharmacology*, *199*(3), 457–480. https://doi.org/10.1007/s00213-008-1099-6

Berto, R. (2014). The Role of Nature in Coping with Psycho-Physiological Stress: A Literature Review on Restorativeness. *Behavioral Sciences*, *4*(4), Article 4. https://doi.org/10.3390/bs4040394

Brielmann, A. A., Buras, N. H., Salingaros, N. A., & Taylor, R. P. (2022). What Happens in Your Brain When You Walk Down the Street? Implications of Architectural Proportions, Biophilia, and Fractal Geometry for Urban Science. *Urban Science*, *6*(1), Article 1. https://doi.org/10.3390/urbansci6010003

Buras, N. H. (2019). *The art of classic planning: Building beautiful and enduring communities*. The Belknap Press of Harvard University Press.

Chan, S. H. M., Qiu, L., Esposito, G., Mai, K. P., Tam, K.-P., & Cui, J. (2021). Nature in virtual reality improves mood and reduces stress: Evidence from young adults and senior citizens. *Virtual Reality*, 1–16. https://doi.org/10.1007/s10055-021-00604-4

Cimprich, B. (1992). Attentional fatigue following breast cancer surgery. *Research in Nursing & Health*, *15*(3), 199–207. https://doi.org/10.1002/nur.4770150306

Cimprich, B. (1993). Development of an intervention to restore attention in cancer patients. *Cancer Nursing*, *16*(2), 83.

Cornwell, H. G. (1976). Necker Cube Reversal: Sensory or Psychological Satiation? *Perceptual and Motor Skills*, *43*(1), 3–10. https://doi.org/10.2466/pms.1976.43.1.3

Davis, N., & Gatersleben, B. (2013). Transcendent Experiences in Wild and Manicured Settings: The Influence of the Trait "Connectedness to Nature". *Ecopsychology*, *5*(2), 92–102. https://doi.org/10.1089/eco.2013.0016

Delavari-Edalat, F., & Abdi, M. R. (2010). Human-Environment Interactions Based on Biophilia Values in an Urban Context: Case Study. *Journal of Urban Planning & Development*, *136*(2), 162–168. https://doi.org/10.1061/(ASCE)0733-9488(2010)136:2(162)

Di Fabio, A., & Kenny, M. E. (2021). Connectedness to nature, personality traits and empathy from a sustainability perspective. *Current Psychology*, *40*(3), 1095–1106. https://doi.org/10.1007/s12144-018-0031-4

Diette, G. B., Lechtzin, N., Haponik, E., Devrotes, A., & Rubin, H. R. (2003). Distraction Therapy With Nature Sights and Sounds Reduces Pain During Flexible Bronchoscopya: A Complementary Approach to Routine Analgesia. *Chest*, *123*(3), 941–948. https://doi.org/10.1378/chest.123.3.941

Dwivedi, S., Thakkar, R., Upadhyay, V., & Kumar, S. (2011). Isolation and Characterization of Actinomycetes Producing Antimicrobial Substance against Human Pathogenic Bacteria. *Journal of Pharmacy Research*, *11*.

Falkenstern, M., Schiffrin, H. H., Nelson, S. K., Ford, L., & Keyser, C. (2009). Mood over matter: Can happiness be your undoing? *The Journal of Positive Psychology*, *4*(5), 365–371. https://doi.org/10.1080/17439760902992415

Fredrickson, B. L., & Levenson, R. W. (1998). Positive Emotions Speed Recovery from the Cardiovascular Sequelae of Negative Emotions. *Cognition & Emotion*, *12*(2), 191–220. https://doi.org/10.1080/026999398379718

Fredrickson, B. L., Mancuso, R. A., Branigan, C., & Tugade, M. M. (2000). The Undoing Effect of Positive Emotions. *Motivation & Emotion*, *24*(4), 237–258. https://doi.org/10.1023/A:1010796329158

Fromm, E. (1955). *The Sane Society*. Rinehart.

Fromm, E. (1956). *The Art of Loving*. https://books.google.nl/books/about/The_Art_of_Loving.html?id=pM8MzzntBRcC&redir_esc=y

Fromm, E. (1963). *The Dogma of Christ: And Other Essays on Religion, Psychology and Culture*. Open Road Integrated Media, Inc. http://ebookcentral.proquest.com/lib/rug/detail.action?docID=4457746

Fromm, E. (1964). *The heart of man: Its genius for good and evil* ([1st ed.]). Harper & Row.

Fromm, E. (1966). *You Shall Be as Gods: A Radical Interpretation of the Old Testament and Its Tradition*. Open Road Media.

Fromm, E. (1976). *The Anatomy of Human Destructiveness*. Open Road Integrated Media, Inc. http://ebookcentral.proquest.com/lib/rug/detail.action?docID=1791671

Fromm, E. (1994). *On Being Human*. Open Road Media.

Hare, T. A., Camerer, C. F., & Rangel, A. (2009). *Self-Control in Decision-Making Involves Modulation of the vmPFC Valuation System*. https://doi.org/10.1126/science.1168450

Hartig, T., Mang, M., & Evans, G. W. (1991). Restorative Effects of Natural Environment Experiences. *Environment and Behavior*, *23*(1), 3–26. https://doi.org/10.1177/0013916591231001

Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and Health. *Annual Review of Public Health*, *35*(1), 207–228. https://doi.org/10.1146/annurev-publhealth-032013-182443

Herchet, M., Varadarajan, S., Kolassa, I.-T., & Hofmann, M. (2022). How Nature Benefits Mental Health. *Zeitschrift Für Klinische Psychologie Und Psychotherapie*, *51*(3–4), 223–233. https://doi.org/10.1026/1616-3443/a000674

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169–182. https://doi.org/10.1016/0272-4944(95)90001-2

Koepp, M. J., Hammers, A., Lawrence, A. D., Asselin, M. C., Grasby, P. M., & Bench, C. J. (2009). Evidence for endogenous opioid release in the amygdala during positive emotion. *NeuroImage*, *44*(1), 252–256. https://doi.org/10.1016/j.neuroimage.2008.08.032

Krabbendam, L. (2005). Schizophrenia and Urbanicity: A Major Environmental Influence--Conditional on Genetic Risk. *Schizophrenia Bulletin*, *31*(4), 795–799. https://doi.org/10.1093/schbul/sbi060

Laland, K. N., & Brown, G. R. (2006). Niche construction, human behavior, and the adaptive-lag hypothesis. *Evolutionary Anthropology: Issues, News, and Reviews*, *15*(3), 95–104. https://doi.org/10.1002/evan.20093

Laumann, K., Gärling, T., & Stormark, K. M. (2003). Selective attention and heart rate responses to natural and urban environments. *Journal of Environmental Psychology*, *23*(2), 125–134. https://doi.org/10.1016/S0272-4944(02)00110-X

Liddicoat, C., Sydnor, H., Cando-Dumancela, C., Dresken, R., Liu, J., Gellie, N. J. C., Mills, J. G., Young, J. M., Weyrich, L. S., Hutchinson, M. R., Weinstein, P., & Breed, M. F. (2020). Naturally-diverse airborne environmental microbial exposures modulate the gut microbiome and may provide anxiolytic benefits in mice. *Science of The Total Environment*, *701*, 134684. https://doi.org/10.1016/j.scitotenv.2019.134684

Løvoll, H. S., Sæther, K.-W., & Graves, M. (2020). Feeling at Home in the Wilderness: Environmental Conditions, Well-Being and Aesthetic Experience. *Frontiers in Psychology*, *11*. https://www.frontiersin.org/articles/10.3389/fpsyg.2020.00402

Mikiten, T. M., Salingaros, N. A., & Yu, H.-S. (2000). Pavements as Embodiments of Meaning for a Fractal Mind. *Nexus Network Journal*, *2*(1), 63–74. https://doi.org/10.1007/s00004-999-0009-5

Moon, P., Muday, J., Raynor, S., Schirillo, J., Boydston, C., Fairbanks, M. S., & Taylor, R. P. (2014). Fractal images induce fractal pupil dilations and constrictions. *International Journal of Psychophysiology*, *93*(3), 316–321. https://doi.org/10.1016/j.ijpsycho.2014.06.013

Nisbet, E. K., & Zelenski, J. M. (2011). Underestimating Nearby Nature: Affective Forecasting Errors Obscure the Happy Path to Sustainability. *Psychological Science*, *22*(9), 1101–1106.

Ochsner, K. N., Silvers, J. A., & Buhle, J. T. (2012). Functional imaging studies of emotion regulation: A synthetic review and evolving model of the cognitive control of emotion. *Annals of the New York Academy of Sciences*, *1251*(1), E1–E24. https://doi.org/10.1111/j.1749-6632.2012.06751.x

Oh, B., Lee, K. J., Zaslawski, C., Yeung, A., Rosenthal, D., Larkey, L., & Back, M. (2017). Health and well-being benefits of spending time in forests: Systematic review. *Environmental Health and Preventive Medicine*, *22*(1), 71. https://doi.org/10.1186/s12199-017-0677-9

O'leary, K. D. (1965). *Preference for Variability of Stimuli as a Function of Experimentally Induced Anxiety*. https://doi.org/10.2466/pr0.1965.16.3c.1202

Orbach, J., Ehrlich, D., & Heath, H. A. (1963). Reversibility of the Necker Cube: I. An Examination of the Concept of "Satiation of Orientation". *Perceptual and Motor Skills*, *17*(2), 439–458. https://doi.org/10.2466/pms.1963.17.2.439

Os, J. V. (2004). Does the urban environment cause psychosis? *The British Journal of Psychiatry*, *184*(4), 287–288. https://doi.org/10.1192/bjp.184.4.287

Park, B.-J., Tsunetsugu, Y., Kasetani, T., Hirano, H., Kagawa, T., Sato, M., & Miyazaki, Y. (2007). Physiological Effects of Shinrin-yoku (Taking in the Atmosphere of the Forest)—Using Salivary Cortisol and Cerebral Activity as Indicators—. *Journal of PHYSIOLOGICAL ANTHROPOLOGY*, *26*(2), 123–128. https://doi.org/10.2114/jpa2.26.123

Peen, J., Dekker, J. J. M., Schoevers, R. A., ten Have, M., de Graaf, R., & Beekman, A. T. F. (2007). Is the prevalence of psychiatric disorders associated with urbanization? *Social Psychiatry and Psychiatric Epidemiology*, *42*(12), 984–989. https://doi.org/10.1007/s00127-007-0256-2

Peen, J., Schoevers, R. A., Beekman, A. T., & Dekker, J. (2010). The current status of urban-rural differences in psychiatric disorders. *Acta Psychiatrica Scandinavica*, *121*(2), 84–93. https://doi.org/10.1111/j.1600-0447.2009.01438.x

Prescott, S. L., & Logan, A. C. (2017). Down to Earth: Planetary Health and Biophilosophy in the Symbiocene Epoch. *Challenges*, *8*(2), Article 2. https://doi.org/10.3390/challe8020019

Robinson, J. M., & Breed, M. F. (2020). The Lovebug Effect: Is the human biophilic drive influenced by interactions between the host, the environment, and the microbiome? *Science of The Total Environment*, *720*, 137626. https://doi.org/10.1016/j.scitotenv.2020.137626

Rothbart, M. K., & Posner, M. I. (1985). Temperament and the Development of Self-Regulation. In L. C. Hartlage & C. F. Telzrow (Eds.), *The Neuropsychology of Individual Differences: A Developmental Perspective* (pp. 93–123). Springer US. https://doi.org/10.1007/978-1-4899-3484-0_5

Sobko, T., Liang, S., Cheng, W. H. G., & Tun, H. M. (2020). Impact of outdoor nature-related activities on gut microbiota, fecal serotonin, and perceived stress in preschool children: The Play&Grow randomized controlled trial. *Scientific Reports*, *10*(1), Article 1. https://doi.org/10.1038/s41598-020-78642-2

Speer, M. E., & Delgado, M. R. (2017). Reminiscing about positive memories buffers acute stress responses. *Nature Human Behaviour*, *1*(5), 0093. https://doi.org/10.1038/s41562-017-0093

Spehar, B., Clifford, C. W. G., Newell, B. R., & Taylor, R. P. (2003). Universal aesthetic of fractals. *Computers & Graphics*, *27*(5), 813–820. https://doi.org/10.1016/S0097-8493(03)00154-7

Sudimac, S., Sale, V., & Kühn, S. (2022). How nature nurtures: Amygdala activity decreases as the result of a one-hour walk in nature. *Molecular Psychiatry*, *27*(11), Article 11. https://doi.org/10.1038/s41380-022-01720-6

Taylor, R. P. (2006). Reduction of Physiological Stress Using Fractal Art and Architecture. *Leonardo*, *39*(3), 245–251.

Tost, H., Reichert, M., Braun, U., Reinhard, I., Peters, R., Lautenbach, S., Hoell, A., Schwarz, E., Ebner-Priemer, U., Zipf, A., & Meyer-Lindenberg, A. (2019). Neural correlates of individual differences in affective benefit of real-life urban green space exposure. *Nature Neuroscience*, *22*(9), 1389–1393. https://doi.org/10.1038/s41593-019-0451-y

Ulrich, R. S. (1984). View Through a Window May Influence Recovery from Surgery. *Science*, *224*(4647), 420–421. https://doi.org/10.1126/science.6143402

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7

Urban Development. (n.d.). [Text/HTML]. World Bank. Retrieved 24 February 2023, from https://www.worldbank.org/en/topic/urbandevelopment/overview

Wilson, E. O. (1984). *Biophilia*. Harvard University Press.

Winecoff, A., Clithero, J. A., Carter, R. M., Bergman, S. R., Wang, L., & Huettel, S. A. (2013). Ventromedial Prefrontal Cortex Encodes Emotional Value. *Journal of Neuroscience*, *33*(27), 11032–11039. https://doi.org/10.1523/JNEUROSCI.4317-12.2013

World Health Organization. (2020). *Basic Documents*. *Forty-ninth edition*.

Yang, X., Garcia, K. M., Jung, Y., Whitlow, C. T., McRae, K., & Waugh, C. E. (2018). VmPFC activation during a stressor predicts positive emotions during stress recovery. *Social Cognitive and Affective Neuroscience*, *13*(3), 256–268. https://doi.org/10.1093/scan/nsy012

Yin, J. (2019). Study on the progress of neural mechanism of positive emotions. *Translational Neuroscience*, *10*(1), 93–98. https://doi.org/10.1515/tnsci-2019-0016