Emotions and bodily sensations evoked by natural and urban environments

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Abstract

While the affective benefits of nature are well documented, the underlying embodied mechanisms remain elusive. Here we mapped the emotional responses and bodily sensations associated with natural versus urban environments in two experiments with a total of 587 participants. In the first experiment, participants rated videos and images of natural and urban environments for emotions and sensory qualities. In the second experiment participants reported the bodily sensations evoked by viewing the environments using topographical self-report method (emBODY). Our findings highlight that the affective impact of the environment depends heavily on arousal, which aligns with the circumplex model of affect. Low-arousal natural stimuli were experienced as the most spacious and passive and had the strongest positive valence, while highly arousing natural environments were rated as the most unpleasant and unsafe. Viewing natural environments also elicited stronger and more widespread bodily sensations than urban environments and these embodied responses may underlie the positive emotions and the restorative powers of nature as well as the negative emotional reactions.

Introduction

The belief that contact with nature improves somatic and mental health spans across cultures from ancient times to the present day (Ward Thompson 2011). This long-standing intuition is supported by an extensive body of research showing that nature benefits health in various ways; it reduces stress, improves cognitive function, reduces blood-pressure and improves mood (Jimenez et al. 2021; McMahan & Estes 2015). Exposure to natural environments decreases negative affect while maintaining or increasing positive affect (Jimenez et al. 2021; Gaekwad et al. 2022). The reason behind the mood-improving effects of nature remain elusive (Gunnarson & Hedblom, 2023). The biophilia hypothesis posits that humans have a genetic tendency to experience positive emotions when being exposed to unthreatening and resourceful natural environments, because our evolution as a species has relied upon the resources nature provides (McSweeney et al. 2021; Ulrich 1993;). Biophilia has been interpreted both as love for living organisms and love for nature, understood as a set of living organisms plus the abiotic environment in which they thrive (Barbiero & Berto 2021). The current study adopts this broader definition. However, like all emotional responses, emotional responses to natural environments are inherently functional and depend on the degree to which an environment signals presence of evolutionary significant resources or hazards (McMahan & Estes 2015). While biophilia dominates the discussion of nature's impact on emotions, biophobia represents the corresponding genetic tendency wherein humans exhibit automatic negative or avoidance reactions to nature (Ulrich 1993; Soga & Evans 2024).

Building on the biophilia hypothesis, the stress recovery theory (SRT) posits that unthreatening nature influences emotions by activating the parasympathetic nervous system, the same activation is not observed with urban stimuli and hence it is considered to support the idea that humans are “innately connected” to nature (Jimenez et al. 2021; Ulrich et al. 1991). Numerous studies have established that nature has beneficial effects on mood when compared with urban environments. Compared to an urban environment, walking in a forest reduces feelings of depression, anger, anxiety, and tension, while also maintaining a positive emotional state and improving performance on tasks requiring working memory (Song et al. 2018; Bratman et al. 2015). Walking through forest versus urban areas decreases the negative feelings and increases feelings of vigor. (Song et al. 2018). Although nature contact inherently occurs at outdoor spaces, nature and elements related to nature also positively affect emotional state when incorporated indoors (McSweeney et al. 2021). Indoor nature contact, such as photos and videos of nature, potted plants and windows with a view of green space have been linked to increased comfort, improved mood and decreased anger and frustration (McSweeney et al. 2015). This kind of indirect nature contact also increases the pleasantness of the space, enhances the joy experienced by those in the space, and reduces feelings of anger and frustration (McSweeney et al. 2021). Similar effects can be brought about through simple images of natural environments. For example, viewing pictures of natural versus urban environments significantly increases the feelings of comfort and relaxation (Yamasita et al. 2021). Most of the previous studies have compared emotions evoked by calm natural environments with those evoked by urban environments, which may partially explain why natural environments seem to affect mood positively (McMahan & Estes, 2015).

Emotions are transient psychophysiological responses that support adaptation to our environment. They organize responses ranging from cognition and perception to the autonomic nervous system (ANS) (Levenson 1994). ANS tone plays an important role in adaptive behaviour, helping us in either pulling towards or pushing away from certain objects, people, ideas or actions (Levenson 1994; Levenson 2003). In addition to preparing us for facing a threat, human evolution likely also favoured the prospects for recovery and restoration (Levenson, 2003). Positive emotions such as amusement and contentment play an important role in recovering from negative emotions and restoring physical balance (Levenson 2003). Somatosensory feedback is a primary driver of conscious emotional experience, and studies show that different emotions (such as anger, fear, disgust…) are associated with statistically separable and culturally universal bodily sensation maps (Nummenmaa et al. 2014; Volynets et al., 2020). These bodily sensation maps thus provide a nonverbal means for accessing the consciously experienced emotions. Because emotions are felt through the body, the restorative capacity of natural environments could thus be mediated through these bodily reactions. However, this hypothesis currently lacks empirical support.

The Current Study

Here we tested the effects of natural and urban environments on subjectively felt emotions and bodily sensation patterns. We presented participants (n=587) with videos and images of natural and urban environments, and recorded their subjective emotional responses and bodily sensation patterns using a topographical self-report method (emBODY). To catch a broader spectrum of emotions evoked by environments, we further split both natural and urban environments into low- and high-arousal conditions based on participants' self-reported ratings on a scale from calm to highly aroused. We show that viewing natural environments elicit stronger and more widespread bodily sensations than viewing urban environments. Furthermore, while low-arousal natural stimuli were observed as statistically significantly more passive and spacious than low-arousal urban environments and had the strongest positive valence, highly arousing natural stimuli were perceived as the most unpleasant and unsafe environment.

Experiment 1: Subjective feelings while viewing images and videos of nature

Methods

To map the subjective feelings while viewing images and videos of nature we collected subjective ratings of discrete emotions and emotion dimensions and qualities of the environment. A total of 434 subjects (220 female, 214 male, mean age = 31.7, SD = 10.3) participated in the experiment.

Stimuli

The stimuli consisted of short silent videos (n = 78, length 4-15 seconds) of natural and urban environments and still images (n = 78) extracted from the videos. A clear distinction between natural and urban environments is not clear-cut, as many real-world settings contain elements of both. For the purpose of this study, natural environments were defined as landscapes or close-ups consisting solely of combinations of flora, water and geological structures with no visible human-made structures or artifacts. The presence of fauna was minimized in the selected natural stimuli to keep the focus on the environment itself. Urban environments included mainly cityscapes, ranging from those completely without nature to those containing some presence of natural elements, such as trees or water.

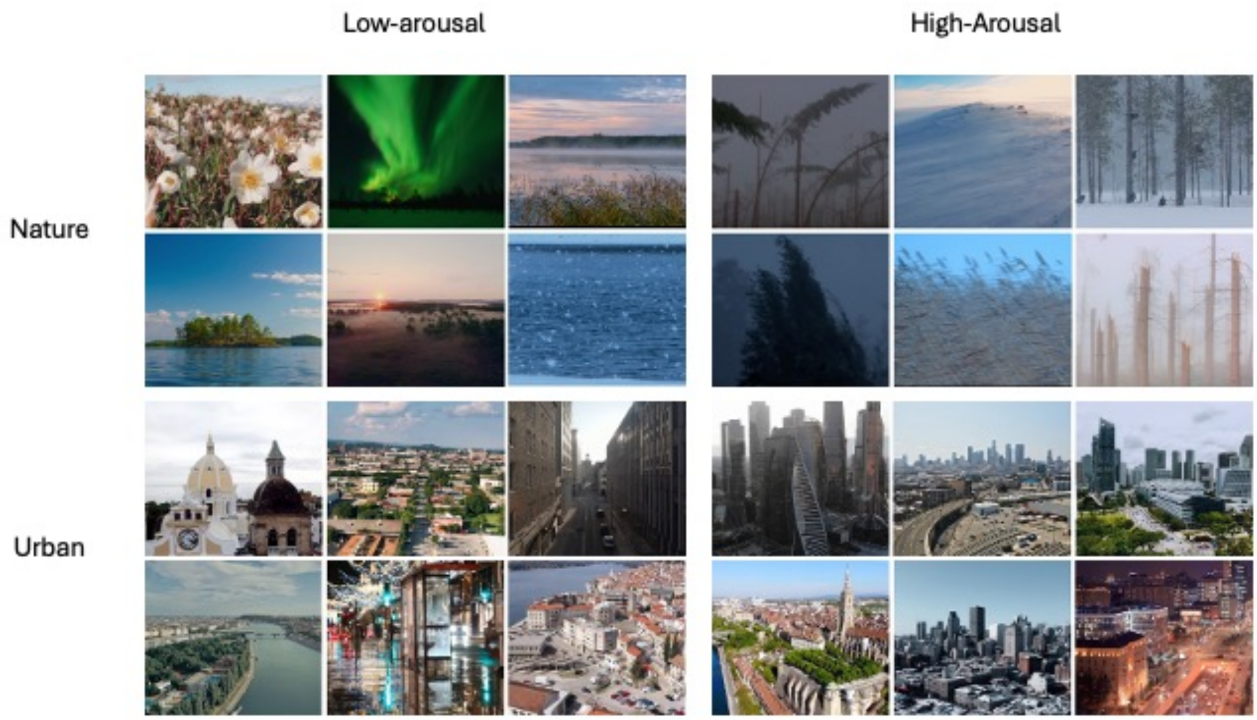

Figure 1: Sample stimuli used in each environment and arousal category

After data collection, we divided both natural and urban stimuli to low-arousal and high-arousal categories for analytic purposes. This division was made based on the data collected in Experiment 1, using the scale calm-aroused, based on the median of the participant ratings. Arousal is defined here as the activation or excitation of the individual as a whole, ranging from deep sleep to extreme excitation, reflected by changes in physiological measures (Duffy, 1957). Figure 2 illustrates the distribution of stimuli for pleasantness and arousal, based on the collected experiment data.

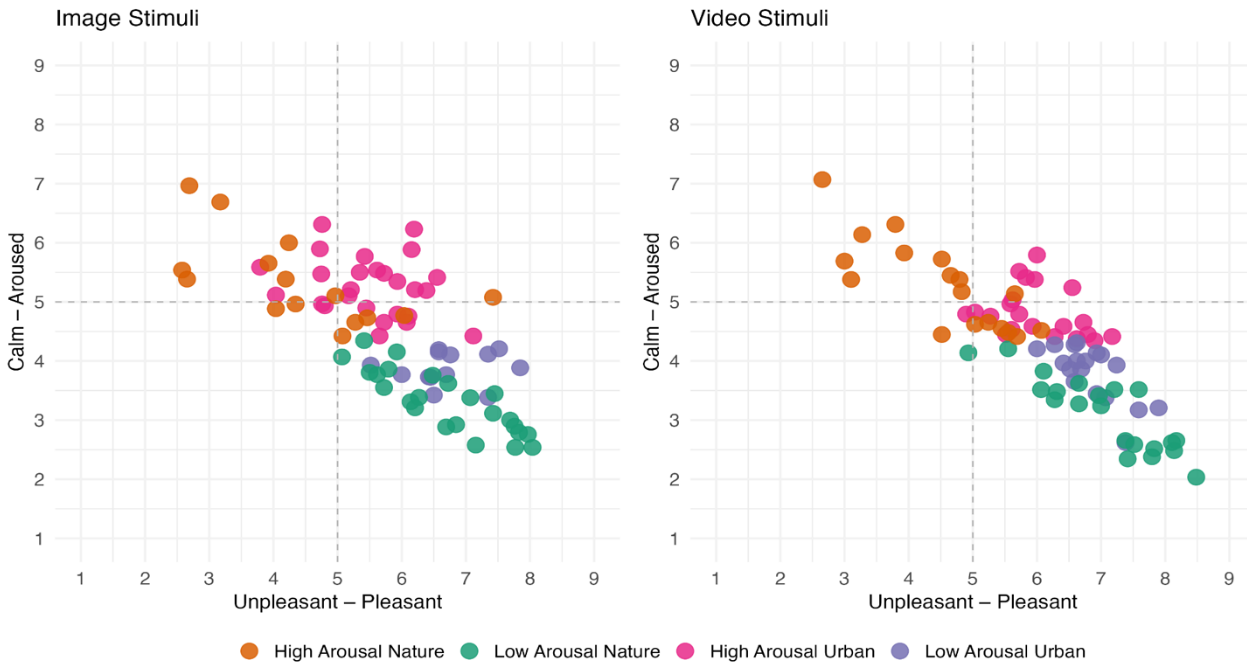

Figure 2: Mean stimulus-wise ratings for pleasantness and arousal.

Emotion Measurements

We used a slightly modified version of the emotion list established in Nummenmaa and Hari (2023). The list consists of basic (e.g. *happiness, sadness, disgust*) and non-basic (e.g. *sublimity, excitement*) emotions. For the purpose of this research, feelings of empathizing, art and effort were discarded and the emotions of fatigue and vigor added to the set. We also added bipolar scales of emotions and basic dimensions, (e.g. *unpleasant – pleasant, cold – warm*) to the set. See Supplementary Information for the full list of measured emotions. Data was acquired on the Gorilla platform (http://gorilla.sc) and the participants were recruited via Prolific (http://prolific.com). A total of 434 subjects (220 female, 214 male, mean age = 31.7, SD = 10.3) were recruited from Prolific, of which 323 (167 female, 156 male, mean age = 32.0, SD = 10.6) gave ratings on the discrete emotions and 111 (53 female, 58 male, mean age = 30.8, SD = 9.3) gave ratings on the bipolar scales of emotions and basic dimensions.

Responses were given using a likert scale from 1-9. For unipolar scales, 1 was "*Not at all*" and 9 was "*Extremely much*". During the experiment, participants were instructed followingly: "*For each emotion listed on the right, select the answer that best describes the extent to which you were experiencing the emotion while watching the image/video*". There were 21 unipolar scales for emotions and for participant comfort each participant gave ratings to seven emotions that would remain the same during the entire task. For the bipolar scales for emotions and basic qualities, there were eight scales and all participants gave ratings on each scale. All the stimuli were presented in a random order on a computer screen. The experiment was divided into batches so that each subject reported subjective emotions to 40 unique stimuli, containing 10 stimuli from each environment category. Each participant would only give ratings for image or video stimuli and only for unipolar or bipolar scales.

Data Analysis

Statistical analysis was conducted using R (R Core Team, 2026; The MathWorks, Inc., Natick, MA) for the subjective emotional responses and MatLab (R2024b) and R for analysing the bodily sensations.We first calculated the mean score for each emotion across all participants. Pearson correlation coefficients were then computed between emotion-wise scores to examine the relationship between participants' responses to measured emotions. To assess the consistency of ratings between different raters, the Intraclass Correlation Coefficient, Two-way Random effects Model, Single Raters (ICC(2,1) was calculated for both datasets. Principal Component Analysis (PCA) was performed to the unipolar scales to reduce dimensionality in the data to reveal underlying patterns and relationships in the data. Two-way ANOVA was then performed based on the first Principal Component, which we interpreted as the valence dimension. Bonferroni corrected pairwise t-tests were used to investigate differences between image and video stimuli within each environment category.

For bipolar scales, a Linear Mixed-effects Model (LMM) was used to examine the effect of the environment on participants' ratings on the measured emotions. The model was run separately for each measured emotion. The calm-aroused scale used to divide stimuli into low- and high-arousal categories was left out of the analysis. The environment category was treated as a fixed effect and to account for non-independence of the dataset, random intercepts were included for participants (to control for individual differences) and for stimulus (to account for variation in responses driven by specific items within a category). Post-hoc pairwise comparisons were calculated using Estimated Marginal Means with Bonferroni correction.

Results

Discrete Emotion Ratings

None of the environments received high mean ratings for negative or unpleasant emotions. Participants consistently assigned the highest ratings for positive emotions to stimuli presenting low-arousal natural environments. Beauty was rated highest for low-arousal nature videos (*Mean (M)* = 7.47, *Standard Deviation (SD)* = 1.7), followed by low-arousal nature images (*M* = 7.37, *SD* = 1.82). Low-arousal nature was also rated highest for liking (video: *M* = 6.6, *SD* = 2.05; image: *M* = 6.49, *SD* = 2.1) and balance (image: *M* = 6.7, *SD* = 2.09; video: *M* = 6.17, *SD* = 2.09). Additionally, amazement, elegance, sublimity and joy also had the highest ratings in the low-arousal nature category. Similarly, low-arousal urban environments were also perceived as positive, though generally with lower ratings than their natural counterparts. Participants rated low-arousal urban environments also as beautiful (image: *M* = 6.37, *SD* = 2.23; video: *M* = 6.07, *SD* = 2.26) and elegant (image: *M* = 5.47, *SD* = 2.54, video: *M* = 5.22, *SD* = 2.5). Participants also reported a moderate level of liking (image: *M* = 5.73, SD = 2.21, video: *M* = 5.33, *SD* = 2.4) for low-arousal urban environments. See Supplementary Information for the full results.

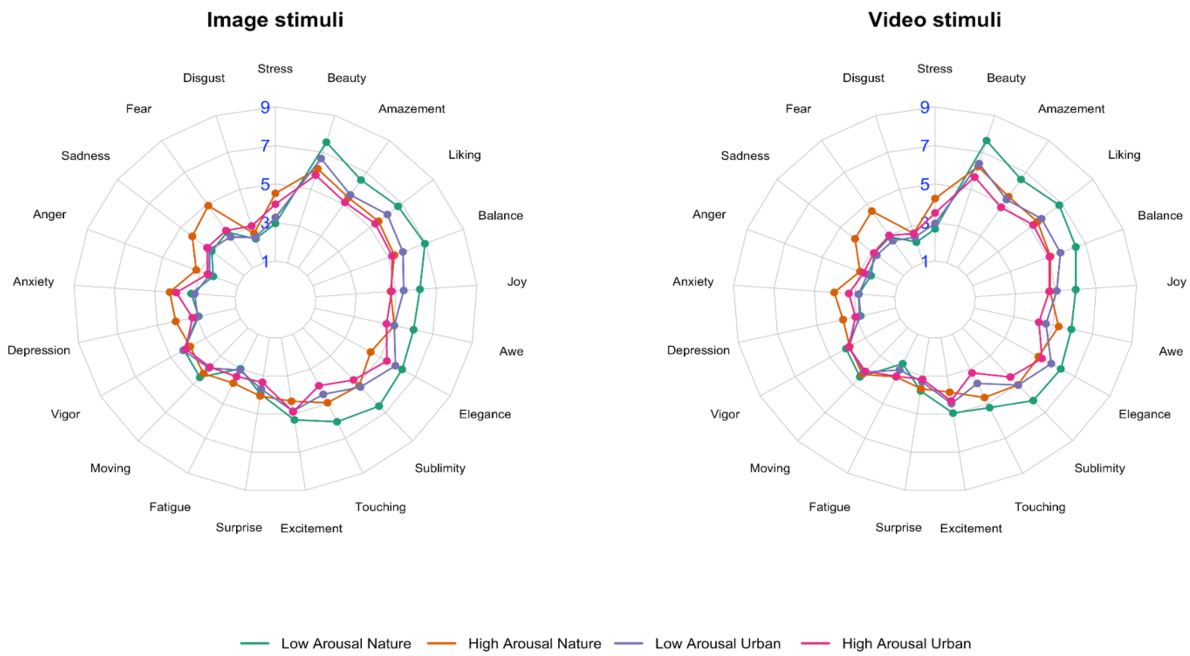

Figure 3: Emotion profiles (means) for each environment and arousal category.

Correlation analysis revealed a clear two-cluster structure. Positive emotions (surprise, moving, excitement, vigor, touching, balance, sublimity, elegance, amazement, awe, joy, beauty and liking) were clustered together. Negative emotions (disgust, anxiety, fear, sadness, anger, stress, depression and fatigue) formed the second cluster and were negatively correlated with positive emotions. Similar structure was observed for both image and video stimuli.

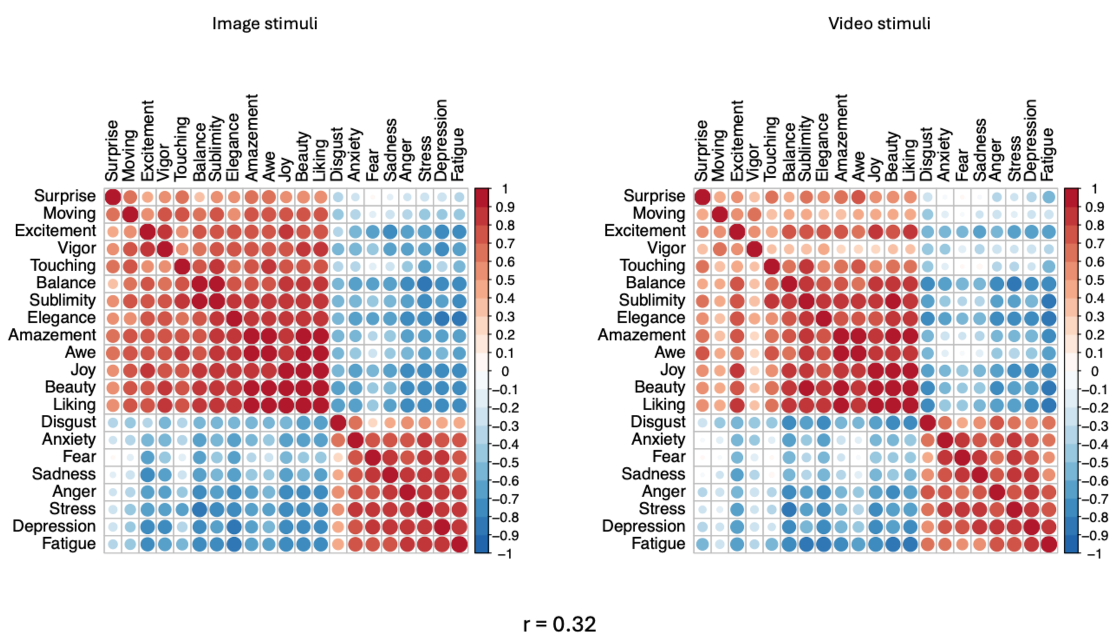

Figure 4: Pearson correlations between the rated emotions.

Principal component analysis revealed that the first principal component (PC1) for both images and videos captured the majority of the variance in the data, explaining 64.8% of variance in image stimuli and 59.6% of variance in video stimuli. Positive emotions (joy, liking, beauty, elegance, sublimity, amazement, balance, awe, vigor, excitement, touching, moving and surprise) had the highest positive loadings on this component. We interpreted PC1 to represent a dimension of emotional valence, with a higher score indicating higher positive valence. To reduce the complexity in the statistical testing, subsequent analysis for the affective impact of different environments was thus based on the PC1 scores capturing most of the variance.

Two-way ANOVA on the PC1 scores showed a statistically significant difference for environment category (image: $F(1,71) = 6.05$, $p = .016$; video: $F(1,74) = 7.54$, $p = .0076$) and a statistically highly significant difference for arousal level (image: $F(1,71) = 32.93$, $p < .001$; video: $F(1,74) = 39.57$, $p < .001$). Additionally, the interaction effect of arousal and environment was also statistically highly significant (image: $F(1, 71) = 5.90$, $p = .018$; video: $F(1,74) = 8.42$, $p = .0049$). Post-hoc analysis revealed low-arousal urban stimuli having statistically significantly lower PC1 score than low-arousal natural stimuli in video stimuli (Diff = -3.19, 95% CI[-5.50, -0.89], $p = .0027$), but not in image stimuli (Diff = -2.42, 95% CI[-5.10, 0.25], $p = .089$). Low-arousal natural stimuli had statistically significantly higher PC1 score than high-arousal natural stimuli (image: Diff = 5.66, 95% CI [3.11, 8.21], $p < .001$; video: Diff = 5.69, 95% CI[3.39, 8.00], $p < .001$) and low-arousal urban stimuli had statistically significantly higher PC1 score than high-arousal natural stimuli (image: Diff = 3.24, 95% CI[0.30, 6.18], $p = .025$; video: Diff = 2.50 95% CI[0.11, 5.00], $p = .0037$). Similarly, low-arousal natural stimuli had statistically significantly higher PC1 score than high-arousal urban stimuli (image: Diff = 4.66, 95% CI[2.40, 6.92], $p < .001$; video: Diff = 5.29, 95% [3.08, 7.54], $p < .001$). There was no statistically significant difference in PC1 scores within each environment between the two different types of media. ICC2 showed a low level of agreement among the raters for all unipolar emotions for both image and video stimuli. Full results are reported in Supplementary Information.

Bipolar Scales of Emotions and Sensory Qualities

The mean ratings for pleasantness were moderate to high for each environmental category. Stimuli of low-arousal environments had the highest mean ratings for pleasantness, safety and participants reported the highest desire to stay while viewing them. Low-arousal nature videos had the highest mean rating for pleasantness ($M = 7.05$, $SD = 2.17$) followed closely by low-arousal urban videos ($M = 6.84$, $SD = 1.77$). Low-arousal natural and urban environments were also consistently rated as most safe with videos of low-arousal urban environments having the highest mean rating (image: $M = 6.51$, $SD = 1.95$; video: $M = 6.26$, $SD = 1.88$) followed by videos of low-arousal natural environments ($M = 6.07$, $SD = 2.26$). Participants reported the highest desire to stay while viewing low-arousal nature environments (video: $M = 4.23$, $SD = 2.62$; image: $M = 4.75$, $SD = 2.68$) and low-arousal urban environments (video: $M = 4.27$, $SD = 2.23$; image: $M = 4.45$, $SD = 2.35$). Low-arousal natural environments were also considered as most passive, relaxed and calm. Natural environments were rated as the most spacious, low-arousal nature category having the highest mean rating, followed by the high-arousal nature category. Participants reported the highest desire to leave, while viewing images and videos of high-arousal natural environments (image: $M = 6.57$, $SD = 2.55$; video: $M = 6.52$, $SD = 2.42$). High-arousal natural environments were also perceived as most tense (video: $M = 5.78$, SD =

2.4; image: M = 5.72, SD = 2.46) and unsafe (video: M = 3.86, SD = 2.21; image: M = 3.99, SD = 2.41). See supplementary information for the full results.

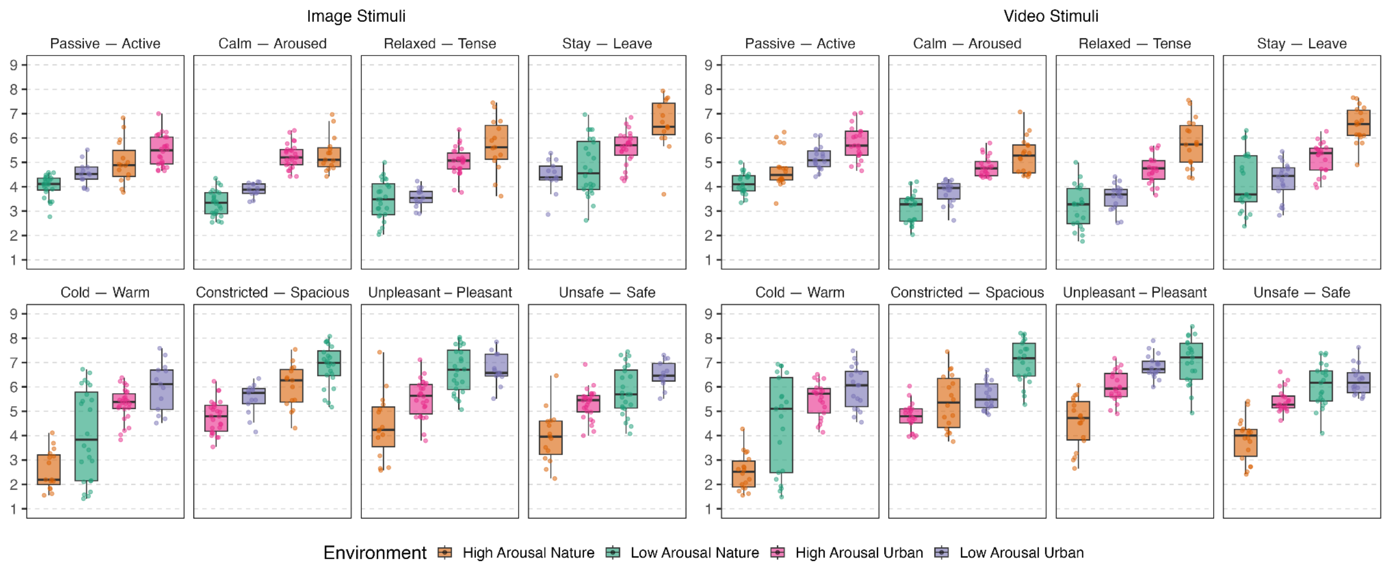

Figure 5: Median (horizontal line) and interquartile range (box) of ratings across environmental categories, and the distribution of individual stimuli (jittered dots).

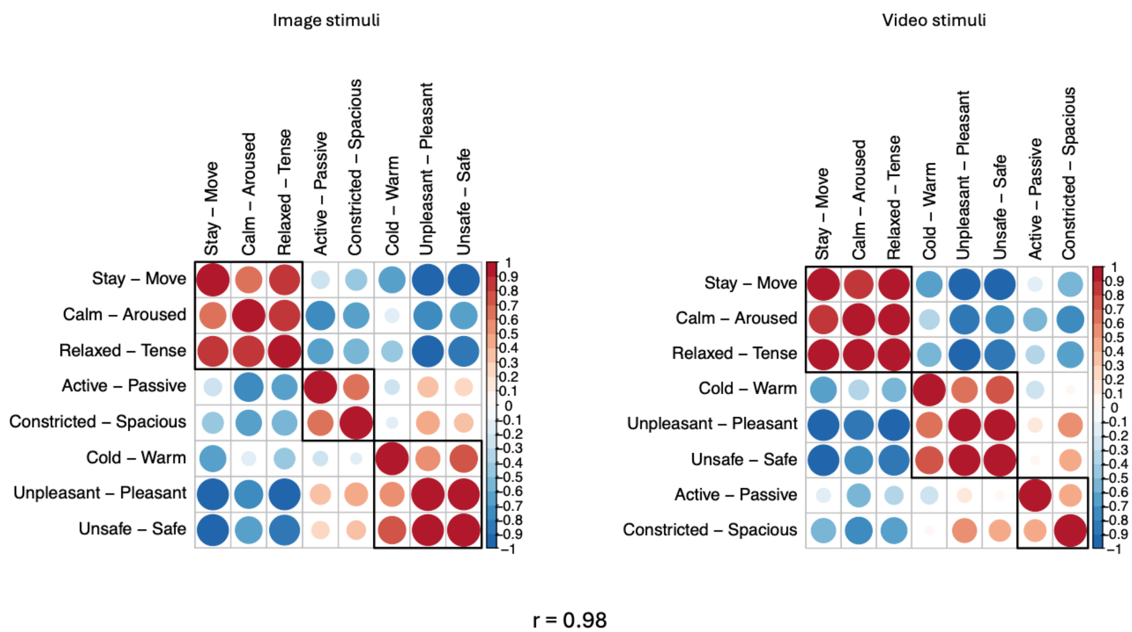

Figure 6: Pearson correlations between the rated emotion scales. Black outlines show the clustering of the rated emotion scales.

Correlation analysis revealed a three-cluster structure where calmness and relaxedness correlate with the willingness to stay in an environment, activeness correlates with constrictedness and feelings of coldness correlate with unpleasantness and not feeling safe. The results were consistent across image and video stimuli.

Principal component analysis for both image and video stimuli had two principal components explaining most of the variance in the data. For images PC1 explained 65.1% of the variance and PC2 explained 21.7% of the variance. For videos PC1 explained 67.1% of the variance in the data and PC2 explained 21.4% of the variance in the data. For both image and video data, the scales calm–aroused, stay–leave and relaxed–tense had positive loadings in PC1 and active–passive, constricted–spacious and stay–leave had positive loadings in PC2.

Linear Mixed-Effects Model revealed that the environment category of the viewed stimuli influenced perceptions of activity, relaxedness, spaciousness and coldness. Low-arousal nature was statistically significantly more passive than low-arousal urban in video stimuli (Estimate = 1.044, SE = 0.198, $p = .0001$), but not in image stimuli (Estimate = 0.572, SE = 0.215, $p = .0573$). Low-arousal nature was also more passive than all other environments. Low-arousal stimuli were generally perceived as more relaxed than high-arousal stimuli. There was no statistically significant difference in relaxedness between low-arousal natural and low-arousal urban stimuli in either media. Both high-arousal and low-arousal natural stimuli were perceived statistically significantly as more cold than urban stimuli. Low-arousal nature stimuli were perceived as statistically significantly more warm than high-arousal natural stimuli (image: Estimate = 1.499, SE = 0.417, $p = .0035$; video: Estimate = 2.022, SE = 0.398, $p < .0001$). Natural environments were rated as statistically significantly more spacious than urban environments, with the exception that there was no statistically significant difference between high-arousal natural and low-arousal urban stimuli. Similarly, low-arousal environments were generally perceived as statistically significantly more spacious than high-arousal environments. However, low-arousal natural stimuli were perceived as statistically significantly more spacious than low-arousal urban stimuli (image: Estimate = 1.400, SE = 0.269, $p < .0001$; video: Estimate = 1.396, SE = 0.266, $p < .0001$).

There was no statistically significant difference in pleasantness between low-arousal natural and low-arousal urban environments in either media. High-arousal natural stimuli was statistically significantly more unpleasant than stimuli of any other category, notably also more unpleasant than high-arousal urban stimuli (image: Estimate = -1.15206, SE = 0.307, $p = .0021$; video: Estimate = -1.478, SE = 0.262, $p < .0001$). High-arousal nature was perceived as statistically significantly more unsafe than other environments, also compared to high-arousal urban stimuli (image: Estimate = -1.366, SE = 0.279, $p = .0001$; video: Estimate = -1.603, SE = 0.240, $p < .0001$). Also, high-arousal natural stimuli were statistically significantly more tense than high-arousal urban stimuli (image: Estimate = 0.700, SE = 0.247, $p < .0359$; video: Estimate = 1.103, SE = 0.247, $p = .0002$). Participants' willingness to leave was also higher while viewing stimuli of high-arousal nature than any other environments, also compared to high-arousal urban stimuli (image: Estimate = 0.939, SE = 0.304, $p = .0168$; video: Estimate = 1.3713, 0.285, $p = .0001$). See Supplementary Information for full results.

There were no statistically significant differences between mean emotion ratings within each environment between the two different types of media. ICC2 showed a low level of agreement among the raters for all bipolar emotions regardless if the stimuli was image or video. These results are reported in the Supplementary Information.

Experiment 2: Bodily Sensations

Methods

To map the bodily sensations associated with viewing different environments, we used a topographical self-report method (emBODY), where the participants are shown a silhouette of a human body alongside the stimuli and are asked to color the regions of the body where they felt changes in activity while viewing the stimuli (Nummenmaa et al., 2014). The stimuli were the same as in Experiment 1. Subjects viewed the stimuli on a computer screen one at a time. Data was acquired on the Gorilla platform and a total of 153 subjects (75 female, 78 male, mean age = 29.6, SD = 7.6) were recruited from Prolific. The experiment was split into batches so that each subject reported bodily sensations to 40 unique images or videos, containing 10 stimuli from each environment category. Subjects only reported bodily sensations and not emotional experiences so that the bodily sensations would not be affected by the emotional evaluations.

The data were screened manually for anomalous painting behavior, such as drawing symbols on bodies or scribbling randomly and responses outside the body area were masked out. Individual bodily responses were first averaged across subjects separately for the images and videos for each environment category. Pixelwise t-tests were conducted to reveal statistically significant sensations for each environment category. Finally, FDR correction (Benjamini & Hochberg, 1995) was applied to control for false positives.

To assess the statistically significant differences between different environments, we used a Negative Binomial Generalized Linear Model (NB-GLM) comparing the effect of the environment category on the average of colored pixels, averaged first over the participant and then over the environment category. The model was run separately for image and video data. Post-hoc pairwise comparisons were performed using estimated marginal means with Tukey's adjustment for multiple comparisons. The results are reported as Incident Rate Ratios (RR), which represent the proportional difference in coloured pixels between categories.

Results

Figure 6 shows statistically significantly activated regions across subjects for each environment type. All the stimuli elicited significant bodily sensations on the head and chest area. Nature stimuli evoked notably stronger bodily sensations both in head and chest area, and also in the limbs. This was most salient for high-arousal natural stimuli, which elicited most widespread bodily sensations throughout the whole body, and also significant activation in the palms. The maps for the image and video stimuli were highly consistent for all categories. Significant Pearson correlations were found for maps of low-arousal nature ($r = .897$, 95% CI [.895, .899]), high-arousal nature ($r = .865$, 95% CI [.862, .868]), low-arousal urban ($r = .918$, 95% CI [.916, .919]), and high-arousal urban ($r = .919$, 95% CI [.918, .921]) categories (all $p < .001$).

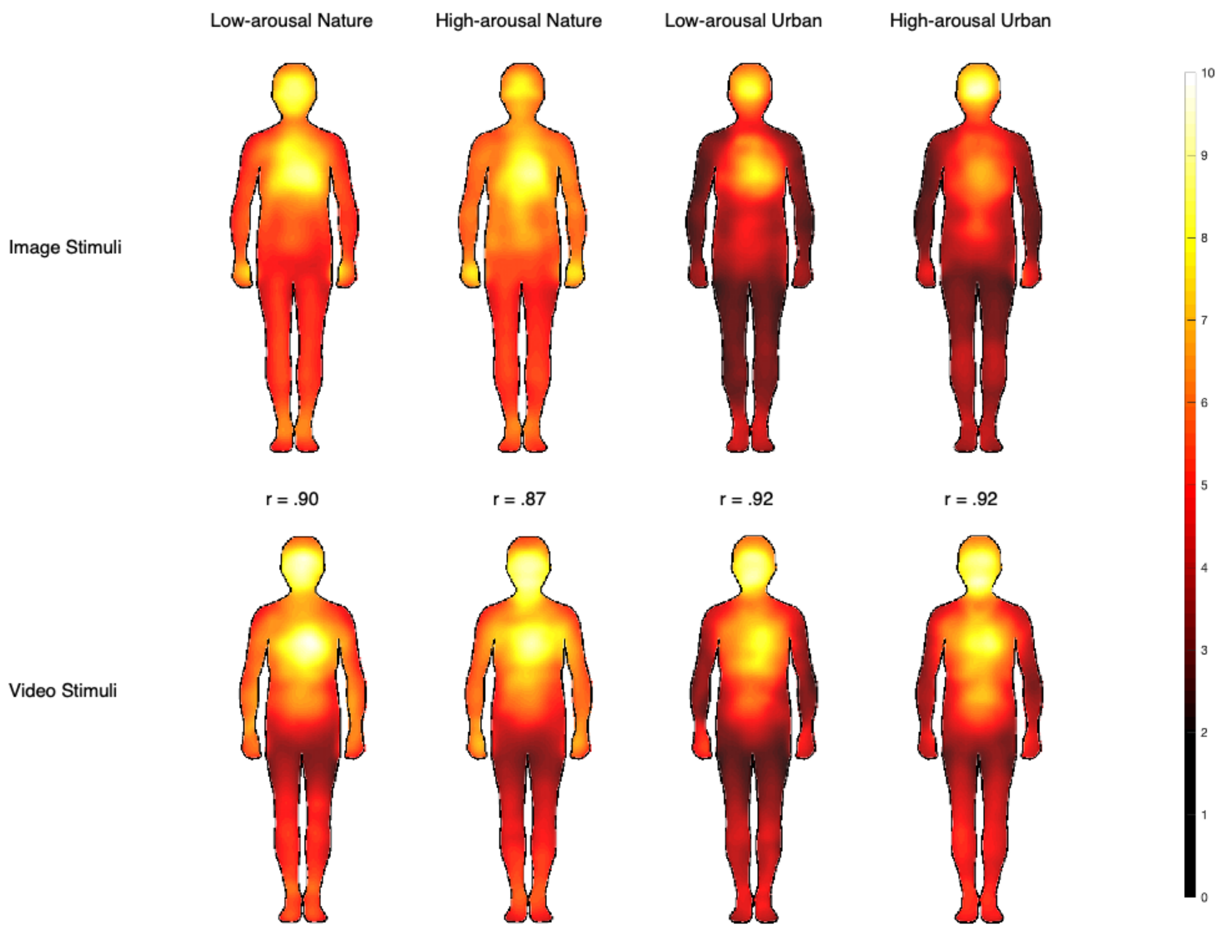

Figure 7: The maps show activated regions across subjects for each environment category. The maps are FDR corrected. Pearson correlations between image and video stimuli are shown in the middle. The t-statistic range is indicated by the colorbar.

The NB-GLM model revealed that in general the nature images and videos evoked stronger bodily responses than the urban environments. For image stimuli, low-arousal nature images had 76% more pixels colored

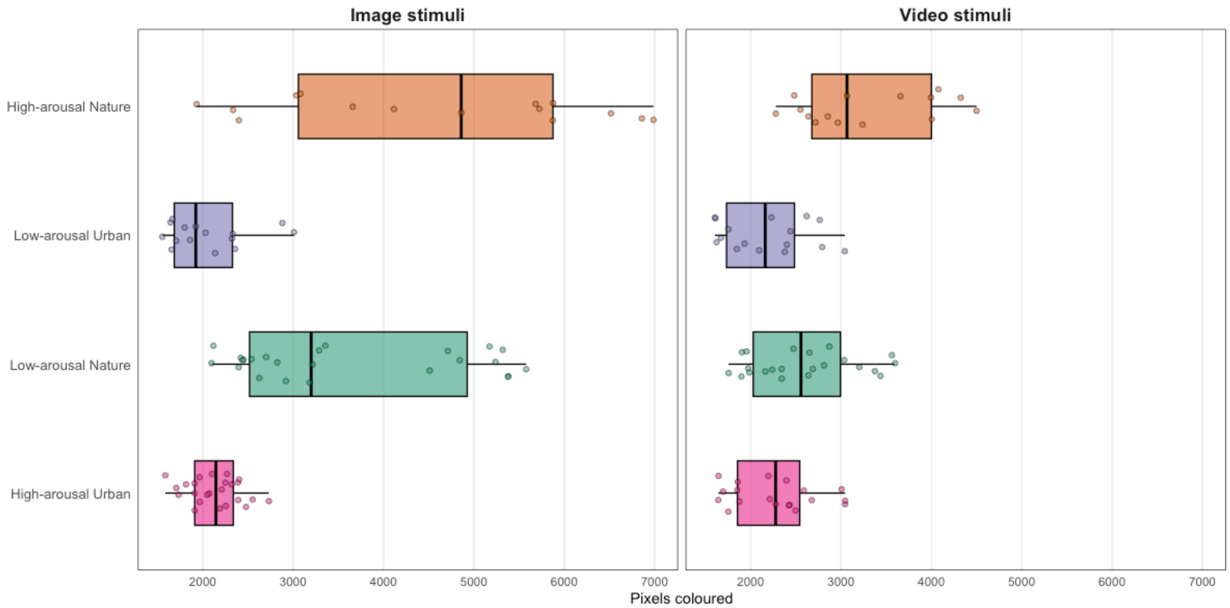

Figure 8: Median (horizontal line) and interquartile range (box) of coloured pixels across environmental categories, and the distribution of individual stimuli (jittered dots).

than low-arousal urban (IRR = 1.756, z = 6.102, p < .0001) and 70% more colored pixels than high-arousal urban (IRR = 1.695, z = 6.524, p < .0001) images. High-arousal nature images had 123% more colored pixels on average than low-arousal urban (IRR = 2.234, z = 7.855, p < .0001) and 116% more colored pixels on average than high-arousal urban (IRR = 2.156, z = 8.335, p < .0001) images. High-arousal nature stimuli had 27% more pixels than low-arousal natural stimuli (IRR = 1.272, z = 2.612, p = .0446). There was no significant difference between low-arousal urban and high-arousal urban images.

For video stimuli, high-arousal nature stimuli had statistically significantly more colored pixels than all other categories. They had on average 27% more colored pixels than low-arousal natural stimuli (IRR = 1.272, z = 3.380, p = .0040), 51% more colored pixels than low-arousal urban stimuli (IRR = 1.513, z = 5.414, p < .0001), and 45% more colored pixels than high-arousal urban stimuli (IRR = 1.450, z = 5.059, p < .0001). Unlike for images, no statistically significant difference was found between low-arousal natural and low-arousal urban stimuli (IRR = 1.189, z = 2.477, p < .0635).

Discussion

Our main finding was that viewing natural environments elicit stronger and more widespread bodily sensations than urban environments. Additionally, natural environments evoked stronger emotional responses compared to urban ones. These emotional patterns were contingent on the arousal levels evoked by the environments, so that highly arousing natural stimuli were observed to be accompanied by increased negative affect and lowly arousing natural stimuli with increased positive affect. Altogether the results thus suggest that the positive emotional effects of nature may be contingent on their calming (low-arousal) features, and that the affective restorative powers of nature might be mediated through the embodied emotional responses.

Arousal-dependent Emotional Responses to Environments

The arousal of the environment was an important determinant of the overall affective response. Our results underlie that people tend to generally prefer low-arousal natural and urban environments, yet we still observed statistically significant differences in the emotional responses between natural and urban environments. The statistically significant interaction effect of environment and arousal in the two-way ANOVAs suggests that the effect of environment is highly dependent on its arousal. This aligns with the circumplex model of affect, which posits that each affective experience is a combination of certain valence and level of arousal (Russel 1980; Posner et al. 2005).

The results highlight that negative affect is increased while viewing highly arousing natural environments, and the high-arousal nature condition was actually the most negatively experienced of all the environments. Such negative affective states evoked by nature are mostly overlooked in the literature considering the emotional effects of the natural environment. We propose that this relates to the perceived safety of the environment, as high-arousing natural environments were evaluated consistently as the least safe, most tense and unpleasant, and the participants were also most willing to leave these environments. From an evolutionary perspective it is evident that nature cannot elicit only positive emotions, since many natural environments and organisms pose threats to survival, which increases negative affect and avoidance behavior (McMahan & Estes, 2015; Kellert & Wilson 1993). While urban environments have largely eliminated numerous dangers posed by the natural environment, the evolved protective fear responses are thought to persist because they are represented in the gene pool (McMahan & Estes 2015; Levenson 1994; Levenson 2003; Ulrich 1993).

In contrast, low-arousal nature was perceived as statistically significantly more passive and spacious than urban environments and had statistically significantly more positive valence in video stimuli. This aligns with the previous research showing that even a brief contact with nature is shown to benefit emotional wellbeing (McMahan & Estes 2015). These effects may also translate to the social domain, as one study showed that viewing pictures of natural versus urban environments increased perceived social belonging, reduced loneliness, improved subjective mood and perceived restorativeness. Another study found that feelings of depression, stress and anxiety were significantly decreased by both actual and indirect nature contact. Based on meta-analysis by McMahan & Estes (2015), exposure to natural environments has a moderate increase in positive affect and smaller but consistent decrease in negative affect. A more recent meta-analysis by Gaekwad et al. (2022) found that exposure to nature had a medium to large effect on both increasing positive and decreasing negative affect. Both found that direct nature exposure had a larger effect than laboratory simulation, however indirect nature contact had a substantial effect as well (McMahan & Estes 2015; Gaekwad et al. 2022). It is worth noting, however, that major heterogeneity exists between the results of different studies, where the type of emotion assessment, type of exposure, study location and mean age of participants have significantly moderated the effect of natural environments on positive and negative emotions (McMahan & Estes 2014; Yao et al. 2021).

Bodily Responses to Natural and Urban Environments

Our results also show, for the first time, that mere exposure to different environments caused salient bodily sensations. Notably, these responses were significantly stronger for natural than urban environments. Previous studies have established that different emotions (such as happiness and fear) are associated with distinct and culturally universal bodily "fingerprints" mediated by the autonomic and visceral changes evoked by the emotions (Nummenmaa 2014; Nummenmaa et al. 2018). Our data suggests that even a brief visual exposure to environmental scenes can lead to substantial embodied responses that likely constitute the basis of the net environmental emotion response. Given the potent emotional and bodily impact of mere images and videos of natural environments, the current study suggests that indirect nature contact can serve as a substitute for real nature and provide benefits for people in indoor spaces. Thus, indirect nature contact could be particularly important for people having functional limitations preventing them from visiting physical natural environments or who live in urban areas with little or no contact to nature (McMahan & Estes 2014). In addition, medical environments, schools and offices could benefit from integration of indirect nature contact to the indoor environments.

Limitations

Future studies should aim for using a more diverse valence-arousal space of natural and urban environment stimuli. Also, we used only visual exposure to nature in both experiments. Environmental perception is inherently multisensory, and auditory, olfactory, and tactile information also contribute to the affective evaluation of the environment. Several studies show that nature sounds are preferred over anthropogenic ones (Franco et al. 2017), thus future studies should address the multisensory integration of the emotional signals evoked by the environments both in the laboratory as well as in the natural environment.

Conclusions

Natural environments cause widespread bodily sensations, and these embodied responses likely constitute the core of the experienced affect. Our findings however highlight the differentiation of these responses depending on the arousal of the environment, stressing the need to move beyond the broad label of "nature" and focus on the specific qualities that trigger positive and negative affective responses. The potent emotional bodily and emotional experiences elicited by images and videos of calming nature would serve as a cost effective intervention for populations and settings with limited access to physical nature.

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References

Barbiero, G., & Berto, R. (2021). Biophilia as Evolutionary Adaptation: An Onto- and Phylogenetic Framework for Biophilic Design. *Frontiers in Psychology*, *12*, 700709. https://doi.org/10.3389/fpsyg.2021.700709

Benjamini, Y., & Hochberg, Y. (1995). Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. *Journal of the Royal Statistical Society. Series B, Methodological*, *57*(1), 289–300. https://doi.org/10.1111/j.2517-6161.1995.tb02031.x

Bratman, G. N., Daily, G. C., Levy, B. J., & Gross, J. J. (2015). The benefits of nature experience: Improved affect and cognition. *Landscape and Urban Planning*, *138*, 41–50. https://doi.org/10.1016/j.landurbplan.2015.02.005

Brooks, A. M., Ottley, K. M., Arbuthnott, K. D., & Sevigny, P. (2017). Nature-related mood effects: Season and type of nature contact. *Journal of Environmental Psychology*, *54*, 91–102. https://doi.org/10.1016/j.jenvp.2017.10.004

Duffy, E. (1957). The psychological significance of the concept of “arousal” or “activation.” *Psychological Review*, *64*(5), 265–275. https://doi.org/10.1037/h0048837

Franco, L. S., Shanahan, D. F., & Fuller, R. A. (2017). A Review of the Benefits of Nature Experiences: More Than Meets the Eye. *International Journal of Environmental Research and Public Health*, *14*(8), 864. https://doi.org/10.3390/ijerph14080864

Fukano, Y., & Soga, M. (2025). The biophilia hypothesis revisited: back to basics, moving forward. *Trends in Ecology & Evolution (Amsterdam)*, *40*(6), 527–528. https://doi.org/10.1016/j.tree.2025.04.001

Gaekwad, J. S., Sal Moslehian, A., Roös, P. B., & Walker, A. (2022). A Meta-Analysis of Emotional Evidence for the Biophilia Hypothesis and Implications for Biophilic Design. *Frontiers in Psychology*, *13*, 750245. https://doi.org/10.3389/fpsyg.2022.750245

Gunnarsson, B., & Hedblom, M. (2023). Biophilia revisited: nature versus nurture. *Trends in Ecology & Evolution (Amsterdam)*, *38*(9), 792–794. https://doi.org/10.1016/j.tree.2023.06.002

Jimenez, M., DeVille, N., Elliott, E., Schiff, J., Wilt, G., Hart, J., & James, P. (2021). Associations between Nature Exposure and Health: A Review of the Evidence. *International Journal of Environmental Research and Public Health*, *18*(9).

Joye, Y., & De Block, A. (2011). “Nature and I are Two”: A Critical Examination of the Biophilia Hypothesis. *Environmental Values*, *20*(2), 189–215. https://doi.org/10.3197/096327111X12997574391724

Joye, Y., & De Block, A. (2025). Our not-so-natural connection to nature. *Trends in Ecology & Evolution (Amsterdam)*, *40*(4), 320–322. https://doi.org/10.1016/j.tree.2025.01.003

Ulrich, R. S. (1993). Biophilia, biophobia, and natural landscapes. In S. R. Kellert & E. O. Wilson (Eds.), The biophilia hypothesis (pp. 73–137). Island Press.

Kondo, M. C., Triguero-Mas, M., Donaire-Gonzalez, D., Seto, E., Valentín, A., Hurst, G., Carrasco-Turigas, G., Masterson, D., Ambròs, A., Ellis, N., Swart, W., Davis, N., Maas, J., Jerrett, M., Gidlow, C. J., & Nieuwenhuijsen, M. J. (2020). Momentary mood response to natural outdoor environments in four European cities. *Environment International*, *134*, Article 105237. https://doi.org/10.1016/j.envint.2019.105237

Levenson, R. W. (1994) Human emotion: a functional view. In: Ekman, P. & Davidson, R. J. (eds.) The Nature of Emotion: Fundamental Questions. Oxford: New York, 123–126.

Levenson, R. W. (2003). Blood, Sweat, and Fears: The Autonomic Architecture of Emotion. *Annals of the New York Academy of Sciences*, *1000*(1), 348–366. https://doi.org/10.1196/annals.1280.016

The MathWorks, Inc. (2024). *MATLAB version 9.14 (R2024b)*. Natick, Massachusetts: The MathWorks, Inc.

McMahan, E. A., & Estes, D. (2015). The effect of contact with natural environments on positive and negative affect: A meta-analysis. *The Journal of Positive Psychology*, *10*(6), 507–519. https://doi.org/10.1080/17439760.2014.994224

McSweeney, J., Rainham, D., Johnson, S. A., Sherry, S. B., & Singleton, J. (2015). Indoor nature exposure (INE): a health-promotion framework. *Health Promotion International*, *30*(1), 126–139. https://doi.org/10.1093/heapro/dau081

Neale, C., Lopez, S., & Roe, J. (2021). Psychological Restoration and the Effect of People in Nature and Urban Scenes: A Laboratory Experiment. *Sustainability*, *13*(11), 6464. https://doi.org/10.3390/su13116464

Nummenmaa, L., Glerean, E., Hari, R., & Hietanen, J. K. (2014). Bodily maps of emotions. *Proceedings of the National Academy of Sciences - PNAS*, *111*(2), 646–651. https://doi.org/10.1073/pnas.1321664111

Nummenmaa, L., & Hari, R. (2023). Bodily feelings and aesthetic experience of art. *Cognition and Emotion*, *37*(3), 515–528. https://doi.org/10.1080/02699931.2023.2183180

Nummenmaa, L., Hari, R., Hietanen, J. K., & Glerean, E. (2018). Maps of subjective feelings. *Proceedings of the National Academy of Sciences - PNAS*, *115*(37), 9198–9203. https://doi.org/10.1073/pnas.1807390115

Posner, J., Russell, J. A., & Peterson, B. S. (2005). The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology.

Development and Psychopathology, *17*(3), 715–734. https://doi.org/10.1017/S0954579405050340

R Core Team (2026). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, *39*(6), 1161–1178. https://doi.org/10.1037/h0077714

Song, C., Ikei, H., Park, B.-J., Lee, J., Kagawa, T., & Miyazaki, Y. (2018). Psychological Benefits of Walking through Forest Areas. *International Journal of Environmental Research and Public Health*, *15*(12), 2804. https://doi.org/10.3390/ijerph15122804

Masashi Soga, & Maldwyn J. Evans. (2024). Biophobia: What it is, how it works and why it matters. *People and Nature*, *6*, 922–931. https://doi.org/10.1002/pan3.10647

Takano, T., Nakamura, K., & Watanabe, M. (2002). Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *Journal of Epidemiology and Community Health (1979)*, *56*(12), 913–918. https://doi.org/10.1136/jech.56.12.913

Ulrich, R. S. (1984). View through a Window May Influence Recovery from Surgery. *Science (American Association for the Advancement of 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

Vincent, E., Battisto, D., & Grimes, L. (2010). The Effects of Presence and Influence in Nature Images in a Simulated Hospital Patient Room. *HERD*, *3*(3), 56–69. https://doi.org/10.1177/193758671000300307

Volynets, S., Glerean, E., Hietanen, J. K., Hari, R., & Nummenmaa, L. (2020). Bodily Maps of Emotions Are Culturally Universal. *Emotion (Washington, D.C.)*, *20*(7), 1127–1136. https://doi.org/10.1037/emo0000624

Ward Thompson, C. (2011). Linking landscape and health: The recurring theme. *Landscape and Urban Planning*, *99*(3), 187–195. https://doi.org/10.1016/j.landurbplan.2010.10.006

Yao, W., Chen, F., Wang, S., & Zhang, X. (2021). Impact of Exposure to Natural and Built Environments on Positive and Negative Affect: A Systematic Review and Meta-Analysis. *Frontiers in Public Health*, *9*, 758457. https://doi.org/10.3389/fpubh.2021.758457