*Supplement to:*

Nature Adds Color to Life:

Less Boredom in Natural Versus Artificial Environments

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**Analysis of Meaning (Study 1, 3, 4)**

Research shows that experiencing the natural world and developing a relationship with nature can be an important contributor to perceptions of meaning in life at the level of individual differences (Howell et al., 2012). Indeed, perceptions of meaning in life mediate the relationship between connectedness to nature and well-being. Boredom is characterized by a lack of perceived meaning. Accordingly, if these trait relations generalize to states, then we may expect that natural environments offer meaning and that this boost in meaning correlates with a reduction in boredom (Fahlman et al., 2009; Van Tilburg 2011; 2019). We measured perceptions of meaning in Study 1, 3, and 4 and explored how it varied across natural and artificial environments and whether it correlated negatively with boredom.

**Study 1**

We found no significant difference in meaning between the natural (*M* = 4.59, *SD* = 1.61) and artificial (*M* = 4.48, *SD* = 1.56) environments, *M*nature – *M*artificial = 0.108, *SE* = .256, *t*(152) = 0.420, *p* = .675, 95%*CI* = [-0.398; 0.613], *d* = .068. Meaning correlated significantly positively with three-item vividness index, *r*(153) = .331, *p* < .001, and single-item vividness measure, *r*(152) = .258, *p* = .001, but, surprisingly, not with boredom, *r*(153) = -.085, *p* = .294.

**Study 3**

Participants who viewed the images of nature (*M* = 4.72, *SD* = 1.55) did not perceive life as significantly less or more meaningful than those who viewed the artificial environments (*M* = 4.49, *SD* = 1.72), *M*nature – *M*artificial = 0.230, *SE* = .342, *t*(90) = 0.674, *p* = .502, 95%*CI* = [-0.448; 0.909], *d* = 0.140. These results do not provide evidence that nature displays (relative to artificial environment ones) alter perceived meaning in life. We found that (state) boredom was significantly negatively correlated with perceived meaning in life, *r*(90) = -.210, *p* = .045, in keeping with prior findings suggesting that seeing life as a whole as meaningful can prevent momentary experiences of boredom (e.g., Van Tilburg et al., 2019). Also the correlation between vividness and meaning was significant, *r*(90) = .246, *p* = .018.

**Study 4**

The design of Study 4 did not allow us to test if nature (vs artificial) displays indirectly contributed to perceived meaning in life (by reducing boredom). The reason for this was that participants saw equivalent amounts of nature and artificial environments. However, participants reported higher levels of perceived meaning in life when the environments caused less boredom on average, *r* = -.278, *p* = .003.

**Emotion Correlations (Study 1 & 5)**

 We measured, aside from self-reported boredom, several other emotions in Study 1 and 5: happiness, awe, and sadness. These emotions correlated significantly with boredom in Study 1, such that boredom was associated with lower levels of happiness and awe, and higher levels of sadness (Table S1).

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| **Table S1***Zero-Order Pearson’s Correlations Between Emotions in Study 1* |
|  | 1. | 2.  | 3.  |
| 1. Boredom | – |  |  |
| 2. Sadness | 0.332 | –  |   |
| 3. Happiness | -0.330 | -0.353 | –  |
| 4. Awe | -0.305 | 0.005(.954) | -0.289 |
| *Note.* Computed correlations used Pearson-method with pairwise-deletion. All correlations were significant at *p* < .001 unless otherwise stated in parentheses. |

 Boredom reported prior to viewing landscapes in Study 5 correlated positively with sadness, negatively with happiness, and negatively but not significantly with awe. Each of these correlations were significant for boredom reported after viewing the landscapes (Table S2).

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| **Table S2***Zero-Order Pearson’s Correlations Between Emotions in Study 5* |
|  | 1. | 2.  | 3.  | 4. | 5. | 6. | 7. |
| 1. Boredom (pre) | – |  |  |  |  |  |  |
| 2. Sadness (pre) | 0.405 | – |  |  |  |  |  |
| 3. Happiness (pre) | -0.411 | -0.567 | – |  |  |  |  |
| 4. Awe (pre) | -0.062(.290) | 0.082(.158) | 0.270 | – |  |  |  |
| 5. Boredom (post) | 0.630 | 0.269 | -0.250 | -0.056(.338) | – |  |  |
| 6. Sadness (post) | 0.387 | 0.744 | -0.464 | 0.034(.563) | 0.397 | – |  |
| 7. Happiness (post) | -0.328 | -0.312 | 0.579 | 0.254 | -0.552 | -0.369 | – |
| 8. Awe (post) | -0.190 | 0.064(.274) | 0.144(.014) | 0.582 | -0.383 | -0.095(.102) | 0.489 |
| *Note.* Computed correlations used Pearson-method with pairwise-deletion. All correlations were significant at *p* < .001 unless otherwise stated in parentheses. |

**Statistical Mediation Analyses (Study 1, 3, & 5)**

**Study 1**

 We used the PROCESS tool (Hayes, 2022) to test if the data supported a statistical mediation pattern where the effect of environment (-1 = artificial, 1 = nature) on boredom was mediated by vividness. We did so first for the aggregated measure of vividness. The partial (direct) effect of the environment on vividness was significant, *B* = .414, *SE* = .104, *t*(152) = 4.002, *p* < .001, 95%*CI* = [.210; .619], as was the partial effect of environment on boredom, *B* = -.345, *SE* = .150, *t*(151) = 2.302, *p* = .023, 95%*CI* = [-.641; -.045]. Partialling out the effect of environment, vividness did not predict boredom significantly, *B* = -.187, *SE* = .112, *t*(151) = 1.671, *p* = .097, 95%*CI* = [-.407; .034]. The indirect effect of environment on boredom through vividness—estimated with 10,000 bias-corrected and accelerated bootstraps, was not significant, *B* = -.077, *SE* = .054, 95%*CI* = [-.194; .022]. The same analysis using the single-item vividness measure revealed similar results: The natural environments increased vividness significantly relative to the artificial one, *B* = .605, *SE* = .124, *t*(151) = 4.879, *p* < .001, 95%*CI* = [.360; .850], and also its partial effect on boredom was significant, *B* = -.352, *SE* = .154, *t*(150) = 2.286, *p* = .024, 95%*CI* = [-.656; -.048]. The partial association between vividness and boredom was not significant, *B* = -.136, *SE* = .094, *t*(150) = 1.444, *p* = .151, 95%*CI* = [-.321; .050], and neither was the indirect effect of environment on boredom through vividness, *B* = -.082, *SE* = .066, 95%*CI* = [-.216; .046]. We thus did not support for statistical mediation in Study 1.

**Study 3**

 We tested the putative statistical mediation by vividness of the effect of environment (-1 = artificial, 1 = nature) on boredom again using Hayes’ PROCESS tool (2022). The partial effect of the environment on vividness was significant, *B* = .644, *SE* = .117, *t*(90) = 5.486, *p* < .001, 95%*CI* = [.411; .878], as was the partial association between vividness with boredom, *B* = -.631, *SE* = .148, *t*(89) = 4.266, *p* < .001, 95%*CI* = [-.925; -.337]. The partial effect of environment on boredom seized to be significant after partialling out vividness, *B* = -.058, *SE* = .191, *t*(89) = .304, *p* = .762, 95%*CI* = [-.436; .321]. The indirect effect of environment on boredom through vividness—estimated with 10,000 bias-corrected and accelerated bootstraps, was significant, *B* = -.407, *SE* = .120, 95%*CI* = [-.652; -.187]. The data of Study 3 indeed supported a pattern where the effect of environment on boredom was mediated by vividness.

**Study 5**

 The design of Study 5 featured a repeated measure of boredom (before vs after the environment was displayed). For the purpose of mediation analysis, we therefore tested for a mediated effect of the environment (-1 = artificial, 1 = nature) on *change* in boredom through vividness. Change is boredom was represented by the difference in boredom before versus after the environments were displayed, with higher scores indicating an increase in boredom. Note that we did not preregister this analysis and it should be regarded as exploratory.

 Using the PROCESS tool (Hayes, 2022), we found that the partial effect of the environment on vividness was significant, *B* = .341, *SE* = .0.60, *t*(292) = 5.681, *p* < .001, 95%*CI* = [.223; .459]. The same was true for the partial effect of environment on change in boredom, *B* = -.374, *SE* = .094, *t*(291) = 3.971, *p* < .001, 95%*CI* = [-.559; -.188], and for the partial association between and boredom, *B* = -.241, *SE* = .087, *t*(291) = 2.771, *p* = .006, 95%*CI* = [-.413; -.070]. Also the indirect effect of environment on boredom through vividness—estimated with 10,000 bias-corrected and accelerated bootstraps, was significant, *B* = -.082, *SE* = .039, 95%*CI* = [-.160; -.006]. The data of Study 5 was thus consistent with vividness mediating the effect of environment on change in boredom.

**Boredom and Geographical Entropy (Study 2)**

In addition to nature, we tested whether landscape monotony is linked to boredom, operationalized as geographical entropy. Monotony has been previously identified as an important characteristic of the environment that can shorten the path to boredom (Danckert et al., 2018). Monotonous environments or monotonous situations offer nothing meaningful to do, are repetitive, and lack novelty (Smith, 1981; Thackray, 1981), making them central to boredom. Quite suitably, much of the extant experimental manipulations of boredom use monotonous stimuli to induce boredom. For example, boredom can be instilled using a repetitive task, such as one consisting of 200 repetitive odds-estimation trials (Van Tilburg & Igou, 2017), using uninteresting videos that are understimulating, such as learning English as a second language (Fahlman et al., 2013; Mercer-Lynn et al., 2014), or situations that lack meaning and novelty, such as solve very easy arithmetic problems (Ulrich et al., 2014). Indeed, some past work has observed links between

 To test whether landscape monotony is related to boredom, we extended the definition of Shannon entropy from information theory to define landscape entropy (Shannon, 1948) and applied it to the data from Study 2. A region high in landscape entropy is diverse, composed of a mixture of natural and urban environments. A region low on landscape entropy is comparatively monotonous, composed majority of a single landscape. We expect regions that are low on entropy, thus very monotonous, to be associated with increased boredom. We define entropy *H* in set *X* of *N* landscapes as a function of each of their proportions *P* within a geographical region.

$$H\left(X\right)=-\sum\_{i=1}^{N}P\left(x\_{i}\right)ln⁡P(x\_{i})$$

The more diverse in landscape a geographical region, the higher the natural landscape entropy. Reversely, the more monotonous the natural landscape within a geographical region, the lower is its landscape entropy (Figure S1). We expect regions that are low on entropy, thus very monotonous, to be associated with increased boredom.

*Figure S1.* Entropy equivalent of land cover composition across three counties.

 Table 1 contains the zero-order correlations between variables. To test if people in areas that are comparatively monotonous express less boredom, we ran a series of random intercept multilevel analyses to account for the regional clustering of individuals (Level 1) within states (Level 2). All predictor variables were *z*-standardized to allow for cross-model comparison. Four models were built in a stepwise manner. An empty model (Model 0) was followed by the inclusion of the landscape entropy variable (Model 1), the regional mobility variable (Model 2), and regional demographics (Model 3).

 Landscape entropy was negatively associated with boredom (Table S3), in line with our hypothesis. When accounting for state-level clustering and additional control variables, the association remains stable (Table S4). These results suggest that less monotonous regions (Figure S2[[1]](#footnote-1)) are associated with less boredom.

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| **Table S3***Zero-Order Pearson’s Correlations Between Boredom Scores, Landscape Entropy, and Regional Correlates in Study 2* |
|  | 1. | 2.  | 3.  | 4.  | 5.  |
| 1. Boredom | – |  |  |  |  |
| 2. Land Entropy | -0.012(.001) |   |   |   |  |
| 3. Mobility | 0.062 | -0.034 |   |   |  |
| 4. Percent Male | -0.026 | -0.059 | 0.531 |  |  |
| 5. Median age | -0.022 | 0.056 | -0.216 | -0.195 | – |
| *Note.* Computed correlations used Pearson-method with listwise-deletion. All correlations were significant at *p* < .001 unless otherwise stated in parentheses. |



**Figure S2**

*Variation in State-Level Landscape Entropy Across the U.S.*

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| **Table S4***Results From Multilevel Models for Boredom in Study 2* |  |  |
|  | **Model 0** | **Model 1** | **Model 2** | **Model 3** |
| *DV***= *Boredom*** | *Estimates* | *95% CI* | *Estimates* | *95% CI* | *Estimates* | *95% CI* | *Estimates* | *95% CI* |
| Intercept | 0.1885 \*\*\* | 0.1783 – 0.1987 | 0.1800 \*\*\* | 0.1690 – 0.1910 | 0.1869 \*\*\* | 0.1757 – 0.1981 | 0.1718 \*\*\* | 0.1604 – 0.1832 |
| Land Entropy |  |  | -0.0106 \*\*\* | -0.0130 – -0.0081 | -0.0139 \*\*\* | -0.0165 – -0.0114 | -0.0114 \*\*\* | -0.0140 – -0.0088 |
| Mobility |  |  |  |  | 0.0088 \*\*\* | 0.0071 – 0.0104 | 0.0080 \*\*\* | 0.0063 – 0.0096 |
| Median Age |  |  |  |  |  |  | -0.0004  | -0.0050 – 0.0043 |
| Percent Male |  |  |  |  |  |  | -0.0278 \*\*\* | -0.0352 – -0.0204 |
| **Model Fit** |
| Marginal *R2* / Conditional *R2* | 0.000 / 0.025 | 0.002 / 0.030 | 0.015 / 0.043 | 0.009 / 0.029 |
| Adjusted *ICC* | 0.03 | 0.03 | 0.03 | 0.02 |
| *AIC* | 30732.777 | -30791.214 | -30885.740 | -30913.917 |
| *Note. N*=75,882, *Nstate*= 39.The adjusted ICC captures Level-2 random effects. \* *p*<0.05   \*\* *p*<0.01   \*\*\* *p*<0.001 |  |  |

The negative association between monotony and boredom adds to the extant literature linking biodiversity to positive psychological outcomes (Aerts et al., 2018; Oishi & Westgate, 2022). Our findings also point to potential urban design decisions that can integrate a variety of landscape features within a space (Kardan et al., 2017) to counter negative psychological states such as boredom and enhance psychological well-being.

**Study 5: Effects on Happiness, Awe, and Sadness**

We examined the change in happiness, awe, and sadness across the two environments with three 2 (time: before, after [within-participants]) × 2 (environment: nature, artificial [between-participants]) mixed-ANOVAs. A significant time × environment interaction for happiness, *F*(1, 292) = 83.124, *p* < .001, $η\_{p}^{2}$= .222, revealed that happiness was higher after viewing the natural environments (*M* = 4.54, *SD* = 1.40) than before (*M* = 4.31, *SD* = 1.31), *M*after – *M*before = .231, *SE* = .090, *t*(146) = 2.568, *p* = .011, 95%*CI* = [.053; .409], *d* = 0.212. Further, happiness was significantly lower after watching the artificial environments (*M* = 3.49, *SD* = 1.44) than before (*M* = 4.48, *SD* = 1.29), *M*after – *M*before = -.993, *SE* = .100, *t*(146) = 9.970, *p* < .001, 95%*CI* = [-1.190; .796], *d* = -0.822. Happiness was higher in the natural vs artificial environment after participants viewed the photographs, *M*nature – *M*artificial = 1.045, *SE* = .165, *t*(292) = 6.375, *p* < .001, 95%*CI* = [.729; 1.380], *d* = 0.744, and no significant difference existed before doing so, *M*nature – *M*artificial = -.159, *SE* = .151, *t*(292) = 1.048, *p* = .295, 95%*CI* = [-.457; .139], *d* = -0.122.

The same analysis for awe also featured a significant time × environment interaction, *F*(1, 293) = 82.117, *p* < .001, $η\_{p}^{2}$= .219. Awe was higher after viewing the natural environments (*M* = 3.11, *SD* = 1.59) than before (*M* = 2.33, *SD* = 1.37), *M*after – *M*before = .784, *SE* = .103, *t*(147) = 7.638, *p* < .001, 95%*CI* = [.581; .987], *d* = 0.628. Conversely, awe was lower after viewing the artificial environments (*M* = 1.75, *SD* = 1.12) than before (*M* = 2.22, *SD* = 1.44), *M*after – *M*before = -.476, *SE* = .094, *t*(146) = 5.079, *p* < .001, 95%*CI* = [-.661; -.291], *d* = -0.419. Awe was higher in the natural vs artificial environment after participants viewed the photographs, *M*nature – *M*artificial = 1.367, *SE* = .160,[[2]](#footnote-2) *t*(265.247) = 8.523, *p* < .001, 95%*CI* = [1.051; 1.682], *d* = 0.991, and no significant difference existed before doing so, *M*nature – *M*artificial = .107, *SE* = .164, *t*(293) = 0.652, *p* = .515, 95%*CI* = [-.215; .429], *d* = 0.076.

We also found a significant time × environment interaction for sadness, *F*(1, 293) = 21.286, *p* < .001, $η\_{p}^{2}$= .068. Sadness was lower after viewing the natural environments (*M* = 2.40, *SD* = 1.54) than before (*M* = 3.09, *SD* = 1.79), *M*after – *M*before = -.689, *SE* = .092, *t*(147) = 7.460, *p* < .001, 95%*CI* = [-.872; -.507], *d* = -0.613. Sadness after watching the artificial environments (*M* = 2.69, *SD* = 1.53) was not significantly different than before (*M* = 2.77, *SD* = 1.60), *M*after – *M*before = -.082, *SE* = .094, *t*(146) = 870, *p* = .386, 95%*CI* = [.-267; .104], *d* = -0.072. Further, significant differences in sadness between the natural vs artificial environment neither emerged after participants viewed the photographs, *M*nature – *M*artificial = -0.288, *SE* = .179, *t*(293) = 1.610, *p* = .108, 95%*CI* = [-.641; -0.064], *d* = -0.188, nor before doing so, *M*nature – *M*artificial = .319, *SE* = .197, *t*(293) = 0.652, *p* = .107, 95%*CI* = [-.069; .708], *d* = 0.188.

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1. Note that Alaska and Hawaii are not represented on the map as they did not reach the 100 cases threshold for inclusion. [↑](#footnote-ref-1)
2. Corrected for violating the assumption of equality of variances, Levene’s *F*(1, 293) = 25.741, *p* < .001. [↑](#footnote-ref-2)