E2IATLAS: A Normative Database of Nature Images with Affective and Self-Transcendent Emotion Ratings

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Article

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Abstract

We introduce the Eco-Emotion Image ATLAS (E2IATLAS), a normative database of 3,161 nature photographs rated by 2,092 participants from 52 countries on six affective dimensions: valence, arousal, awe, compassion, connectedness, and gratitude. Images were assembled from open-access affective-science databases and photographic repositories, spanning eight content categories from pristine landscapes to human-impacted environments, with about 50 raters per image sampled across all five major climate zones. Factor analysis and network modelling converged on a three-factor structure: a dominant Positive Transcendence dimension uniting valence, awe, connectedness, and gratitude; a largely orthogonal Activation factor defined by arousal; and a partially independent Compassion factor. Cluster analysis identified four image profiles, including a Distress-Compassion profile — negative valence with elevated compassion — concentrated in environmental-issue imagery and invisible in valence-arousal space. Semantic content predicted affective responding substantially better than low-level visual features, with the built-infrastructure ratio the dominant suppressor of self-transcendent responding. Hedonic valence was near-universal across cultures, whereas self-transcendent dimensions showed moderate regional variation and a continuous latitude gradient. E2IATLAS is a shared platform for affective neuroscience, environmental psychology, and conservation-communication research.

Introduction

Human societies currently face an accelerating environmental polycrisis (Lawrence et al., 2022; Rakowski et al., 2025). Global surface temperatures have risen by approximately 1.1°C above pre-industrial levels, with the past decade constituting the warmest on record (IPCC, 2023). Biodiversity is declining at rates estimated to be 100–1,000 times the natural background (Pimm et al., 2014), with approximately one million species currently threatened with extinction (IPBES, 2019). At the same time, ecosystem degradation, air pollution, and land-use change are now recognized as major determinants of global health burden (Bratman et al., 2019; Campbell-Lendrum et al., 2023; Doell et al., 2023; Polemiti et al., 2024; Romanello et al., 2024; Whitmee et al., 2015; Xu et al., 2023). These converging crises are not merely scientific or material challenges: they are increasingly constitutive of everyday psychological experience. Surveys across 10 countries find that more than two-thirds of adults report significant worry about climate change, and climate-related anxiety — characterized by chronic fear, helplessness, and preoccupation with environmental futures — has emerged as a clinically significant and population-level phenomenon (Clayton, 2020; Hickman et al., 2021; Ogunbode et al., 2022). In parallel, public discourse and scientific attention have begun to recognize a broader spectrum of emotional reactions to environmental change, including grief over ecological loss, anger at environmental injustice, and awe and gratitude in response to encounters with the non-human world (Albrecht et al., 2007; Gordon et al., 2017rımer-Aydınlı et al., 2025; Pihkala, 2020, 2022).

These reactions have been conceptualized under the term eco-emotions (Kırımer-Aydınlı et al., 2025): affective states specifically directed at the natural world and arising in response to experiences of, changes in, or relationships with non-human nature (Clayton, 2020). Eco-emotions span a wide hedonic range. At the negative pole, they include solastalgia — distress arising from lived experience of environmental degradation (Albrecht et al., 2007) — as well as ecological grief, eco-anxiety, and climate-related guilt. At the positive pole, they encompass the self-transcendent emotions (STEs): a family of states characterized by a temporary dissolution of self-boundaries and an orientation beyond the individual self toward other persons, living beings, or natural phenomena (Stellar et al., 2017; Yaden et al., 2017). Prototypical STEs include awe — a response to vast, complexity-exceeding stimuli that challenge existing mental schemas (Keltner & Haidt, 2003); connectedness — a felt sense of belonging to and kinship with the natural world (Nisbet et al., 2011); gratitude — an orientation of appreciation toward nature as a source of benefit (Emmons & Mishra, 2011); and compassion — empathic concern for suffering directed at other living beings or ecosystems (Goetz et al., 2010). STEs occupy a theoretically distinct position within the broader landscape of eco-emotions: unlike distress-based reactions, they are intrinsically other-oriented and, by hypothesis, capable of motivating prosocial and pro-environmental action (Piff et al., 2015; Rudd et al., 2012; Smith et al., 2026; Yang, 2018).

A now-substantial body of empirical evidence documents that contact with natural environments confers broad psychological benefits (Bratman et al., 2019, 2024; Hartig et al., 2014; S. Kaplan, 1995). Exposure to nature — whether through direct immersion, passive observation, or brief urban green space encounters — reliably reduces physiological stress markers including cortisol and blood pressure (Baquedano et al., 2026; Sudimac et al., 2022; Ulrich et al., 1991; White et al., 2019), improves attentional capacity and cognitive performance (Berman et al., 2008; S. Kaplan, 1995), and is associated with lower rates of depression, anxiety, and rumination in both experimental and epidemiological designs (Bratman et al., 2015; Sudimac et al., 2022; White et al., 2019). A meta-analysis of 143 studies found that nature exposure was associated with significant reductions in negative affect and increases in positive affect across a wide range of populations and settings (McMahan & Estes, 2015). Two theoretical frameworks have dominated this literature. Stress Reduction Theory (Ulrich, 1983; Ulrich et al., 1991) proposes that natural environments rapidly down-regulate physiological arousal through evolutionary affiliation with scenes signalling safety and resource availability. Attention Restoration Theory (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995) emphasizes the effortless, involuntary fascination afforded by natural settings as a mechanism for replenishing directed attentional resources depleted by cognitive demands. Critically, both frameworks predict that these benefits are mediated not only by the absence of urban stressors but by the positive affective and self-transcendent qualities that natural scenes actively elicit — awe at vast landscapes, felt kinship with living systems, gratitude for natural beauty — suggesting that STEs are not merely correlates but theorised mediators of nature's restorative effects (Chen et al., 2022; Joye & Bolderdijk, 2015; Piff et al., 2015; Zhang et al., 2014).

Empirical evidence specifically supports a link between self-transcendent emotional experience and both pro-environmental and prosocial behaviour (Isham et al., 2022). Awe, experimentally induced through nature exposure or vast visual scenes, increases pro-environmental intentions, reduces self-reported materialism, and fosters collective identity (Chirico et al., 2023; Joye & Bolderdijk, 2015; Piff et al., 2015). Nature connectedness — a trait-level analogue of state connectedness — is among the most reliable predictors of subjective well-being, voluntary pro-environmental behaviour, and conservation motivation across cultures (Nisbet et al., 2011; Restall & Conrad, 2015; Tam, 2013). Gratitude toward nature has been linked to reduced overconsumption, greater willingness to protect natural resources, and positive affect as a buffer against environmental anxiety (Tam, 2022). Compassion directed at non-human nature underlies moral concern for biodiversity and animal welfare, and is theorized to motivate biospheric value orientations that predict conservation behaviour independently of self-interest (de Groot & Steg, 2008; Goetz et al., 2010; Jacobs & McConnell, 2022; Schultz, 2000; Stern, 2000; Stern et al., 1993; Stern & Dietz, 1994; Wallach et al., 2018). Across these literatures, a consistent mechanistic picture emerges: STEs expand the boundaries of moral concern beyond the individual self, shifting motivation from personal interest toward collective or biospheric welfare (Janhonen et al., 2026)— making them theoretically central to both the psychological benefits of nature contact and the affective drivers of environmental engagement (Bethelmy & Corraliza, 2019; Jacobs & McConnell, 2022; McConnell et al., 2021; Ruckert et al., 2025; Zelenski & Desrochers, 2021).

For both practical and experimental reasons, visual images of natural environments have become a primary methodological tool in this research (Berto, 2005; Kühn et al., 2021; Mayer et al., 2009; Neill et al., 2019; Velarde et al., 2007). Studies demonstrate that even brief exposure to photographs or videos of nature reliably reproduces the restorative and affective benefits observed with real-world nature contact, including reductions in stress, improvements in mood, and increases in nature connectedness (Berto, 2005; Mayer et al., 2009; Neill et al., 2019; Velarde et al., 2007). Images afford the precise experimental control — standardized content, controlled presentation duration, counterbalanced stimulus sets — that is essential for isolating specific visual and semantic determinants of affective responding (Huynh et al., 2026). They are also indispensable for environmental neuroscience (Baquedano et al., 2026) as well as online research, which now constitutes a dominant modality in affective and environmental psychology (Kurdi et al., 2017). As the volume and complexity of online behavioural research increase, a growing number of researchers require access to pretested images that systematically vary in affective content. Without validated stimulus sets, investigators are compelled to assemble visual materials in an ad hoc manner — a practice that is time-consuming, methodologically inconsistent, and fundamentally limits the comparability and cumulative generalizability of findings across studies (Kurdi et al., 2017).

Existing Normative Databases and Their Limitations

Despite this theoretical centrality, the infrastructure for studying STEs in nature imagery is underdeveloped. Existing databases fall into two traditions, neither of which provides the required coverage. Broad-spectrum affective databases — IAPS (Lang et al., 1997), NAPS (Marchewka et al., 2014), OASIS (Kurdi et al., 2017), and GAPED (Dan-Glauser & Scherer, 2011) — span the full valence-arousal range but contain little nature imagery and record only valence and arousal, omitting the self-transcendent domain. Domain-specific environmental databases are more ecologically focused but equally limited affectively: ACI (Lehman et al., 2019), FAICC (Ottavi et al., 2021), EXCEED (Magalhaes, 2018), e-NatPOEM (Dal Fabbro et al., 2021), SNED (Bendall et al., 2024), and Project Soothe (MacLennan et al., 2023) assess valence, arousal, and restorative or soothing qualities, but none provides explicit norms for awe, connectedness, gratitude, or compassion. Researchers who wish to select images differing in self-transcendent content therefore have no validated stimulus set to draw on.

Three further limitations compound this gap. First, stimulus control: when neuroimaging links nature imagery to brain or autonomic responses, category differences may reflect emotional content or confounded low-level visual properties — saturation, luminance, and edge complexity co-vary with naturalness (Kragel et al., 2019; Kragel & LaBar, 2016; Kühn et al., 2021; Menzel & Reese, 2021), and no existing nature database pairs affective norms with both low-level visual and AI-derived semantic feature data. Second, geography: existing databases are assessed almost exclusively in WEIRD samples (Henrich et al., 2010), an assumption of universality that is especially problematic for STEs, which are theoretically sensitive to cultural variation in self-construal and nature-relatedness (Markus & Kitayama, 1991; Tam, 2013). Third, a positive-content bias: existing sets predominantly cover pleasant, restorative imagery while leaving negatively valenced environmental content — pollution, deforestation, degraded ecosystems — unmeasured, precisely the territory most relevant to conservation communication and climate psychology.

The Present Database

We present the Eco-Emotion Image ATLAS (E2IATLAS), a normative database of 3,161 nature photographs rated by 2,092 participants from 52 countries on six affective dimensions: valence, arousal, awe, compassion, connectedness, and gratitude. The stimulus pool was assembled from 16 open-access databases and repositories, spanning eight super-categories from pristine landscapes and wildlife to human-impacted environments. Each image was rated by ~ 50 raters recruited across all five major Köppen–Geiger climate zones, yielding cross-cultural norms that go beyond the WEIRD-sample dominance of existing databases. Beyond affective ratings, E2IATLAS includes low-level visual features (luminance, saturation, edge complexity, spectral power, symmetry, chromaticity) and AI-derived semantic scene descriptors (sky, water, vegetation, and infrastructure proportions; horizon height; openness; perspective). The database addresses four questions: (1) the factor structure of affective responding to nature imagery when self-transcendent dimensions are included; (2) whether nature images cluster into interpretable affective profiles; (3) how well visual and semantic features predict affect, and which dominate; and (4) the extent to which affective responses are universal versus culturally differentiated. E2IATLAS is freely available at OSF (https://osf.io/tz74d).

Methods

Stimuli

The E2IATLAS stimulus pool comprised 3,161 nature photographs drawn from 16 open-access affective image databases and photographic repositories. Sources were selected to maximise content diversity and include both widely used affective science stimuli (IAPS, NAPS, OASIS, Project Soothe, e-NatPOEM, SNED, FAICC, EmoPicS) and thematically focused collections covering climate, agriculture, and environmental impact (Climate Visuals, EXCEED, ACI). All images were standardized to one of three aspect-ratio formats: square (600 × 600 px), portrait (400 × 600 px), or landscape (600 × 400 px), preserving original composition while ensuring a consistent maximum dimension across all stimuli. Three independent coders (HT, RZP, LM) assigned the images to one of 21 fine-grained content categories, subsequently grouped into eight theoretically motivated super-categories: (1) Natural Landscapes (37.0%), (2) Animals & Wildlife (20.0%), (3) Built Environment (13.9%), (4) Water & Marine (12.5%), (5) Environmental Issues (10.2%), (6) Weather & Atmosphere (3.6%), (7) Agriculture (2.3%), and (8) Other (0.5%). The Environmental Issues super-category intentionally incorporates threatening and negatively valenced content — natural hazards, pollution, deforestation, climate impacts — to ensure full affective range coverage, distinguishing E2IATLAS from databases focused exclusively on aesthetically pleasant imagery.

Participants and Procedure

Participants and procedure. N = 2,092 participants (50.2% female; Mean age = 35.3 years, SD = 12.1) were recruited via Prolific Academic using targeted geographic stratification across 52 countries and all five major Köppen–Geiger climate zones. Ethical approval was obtained from the local Board for Ethical Questions in Science of the University of Innsbruck in Austria [90/2022] and the study was conducted in accordance with the Declaration of Helsinki; all participants provided written informed consent. Participants with Prolific approval rates below 95% were excluded prior to recruitment to ensure data quality. Each participant rated a randomly assigned subset of approximately 75 images (M = 76.6 per participant) on six affective dimensions: valence (1 = very unpleasant, 9 = very pleasant), arousal (1 = very calm, 9 = very activated), awe, compassion, connectedness, and gratitude (all: 1 = not at all, 9 = extremely). Dimension definitions and scale anchors were presented at the start of the task. Participants were instructed to allow each image to affect them before responding, to use the full range of the scale, and to report their own momentary feelings rather than normative or expected responses. Each image was presented for a minimum viewing duration of two seconds, after which participants provided self-paced ratings on all six affective dimensions. To ensure balanced category representation across participants, the stimulus pool was divided into 40 randomized image sets of 75 to 83 stimuli each, constructed to contain an equal proportion of images from every content category. Participants were randomly assigned to one of these sets upon entering the study, ensuring that each image received ratings from an approximately equivalent number of independent raters while maintaining full category coverage within each participant's rating session. Thus, each image received ratings from 48–55 independent raters (M = 50.6), and image-level means across all six dimensions constitute the E2IATLAS normative database. Median task completion time was 17.5 minutes. In total 160.334 ratings were collected.

Data Quality and Automated Response Screening

A multi-layered screening approach was employed to safeguard data integrity. Platform-level quality controls excluded participants with prior approval rates below 95%. Sessions completed in under ten minutes were excluded. The rating task itself reduces AI-contamination risk relative to open-text paradigms: participants responded exclusively via Likert-scale sliders with no free-text input at any point. The primary automated threats in such tasks — auto-clickers and scripted form-fillers — are precisely those that response time screening is best suited to detect.

Image Feature Extraction

Two sets of image features were extracted for each stimulus. *Low-level visual features* (eight in total) were computed in MATLAB using Image Processing Toolbox routines: (1) mean R, G, and B channel values (each on a 0–1 scale; i.e., 3 features); (2) saturation (mean of the HSV S channel); (3) colour temperature (R/B chromaticity ratio); (4) brightness and (5) contrast (mean and standard deviation of Rec. 709 luminance, respectively); (6) luminance; (7) edge complexity (total Canny edge pixel count, normalized by image area); (8) spectral power (mean log-amplitude in the low-frequency band of the 2D Fourier spectrum); and (9) bilateral symmetry (Pearson correlation between the left half and its mirror-reflected right counterpart). These eleven features were selected to represent the primary dimensions of low-level perceptual processing implicated in affective responses to visual stimuli.

Automated semantic features were extracted using SegFormer-B0 (Xie, 2021), a transformer-based segmentation model fine-tuned on ADE20K (150 classes; Hugging Face: nvidia/segformer-b0-finetuned-ade-512-512), and DPT Large (Ranftl et al., 2021), a monocular depth estimation model. Both models were applied at native image resolution without fine-tuning. For each image, four area fractions were derived from the segmentation output by aggregating pixel proportions across semantically related label groups: sky (including clouds), water (sea, river, lake, waterfall), vegetation (trees, grass, plants, forest), and infrastructure (buildings, roads, bridges, and related urban structures). Relative horizon height was estimated as the median row of the sky–non-sky boundary across image columns, normalised by image height. Scene openness was classified as open, semi-open, or enclosed based on the maximum of sky ratio and far-field depth proportion. Perspective was assigned to one of four categorical labels (immersed, ground-level, elevated, high viewpoint) combining horizon height and depth statistics.

Statistical Analyses

Inter-rater reliability was assessed for each affective dimension using a cross-classified random-effects model (stimuli and participants as crossed random intercepts; lme4), partitioning total variance into image-level (ICC_{image}), person-level (ICC_{person}), and residual components. ICC_{image} indexes the degree to which images can be reliably rank-ordered on a given dimension — values near zero indicate that the dimension reflects primarily individual response tendencies rather than a stable stimulus property. As a complementary index, split-half reliability was computed by randomly partitioning raters into two halves, correlating image-level means across halves, and applying the Spearman-Brown correction. Internal consistency of the four self-transcendent emotion ratings was assessed via Cronbach's α. Category differences were tested with the same crossed random-effects structure, with content category as a fixed effect.

The affective structure of image-level means was characterised using three complementary approaches. Principal component analysis (PCA, oblimin rotation) described the dominant axes of variance. Exploratory factor analysis (EFA; maximum likelihood estimation, oblimin rotation) was used to extract a confirmatory factor solution with the number of factors determined by parallel analysis (100 iterations). A Gaussian Graphical Model (GGM; EBICglasso regularization, $\gamma = 0.5$) (E. I. Epskamp S. ,. &. Fried, 2018) estimated the partial correlation network among the six dimensions, providing insight into direct dependencies after controlling for all other dimensions. Network centrality indices (Strength, Betweenness) were computed to identify hub nodes.

A Self-Transcendence (ST) Index was constructed as the mean of the three self-transcendent dimensions reliably elicited by nature imagery as such (awe, connectedness, gratitude). Compassion was excluded from this composite because it showed partial factorial independence in the six-dimensional structure (see Results) and, in the context of nature images, is more plausibly directed at other living beings depicted in or associated with the scene than at the self-transcendent response to nature itself. The remaining three dimensions are all classified as self-transcendent emotions in the affective science literature (Stellar et al., 2017), and the single-factor solution on these four dimensions yielded acceptable fit. Stimulus profiles were identified via hierarchical cluster analysis (Ward D2 linkage, Euclidean distance on z-scored emotion profiles, $k = 4$ selected by elbow criterion and interpretability).

To assess how well image-level affective responses can be predicted from visual and semantic features, we trained four regression models — ordinary least squares, Elastic Net (α and λ jointly tuned over a 10×20 grid), and Random Forest (500 trees; $mtry \in \{3, 5, 7, 9\}$ tuned via 10-fold cross-validation) — on the combined feature set (11 low-level visual features and 5 continuous semantic features). Models were trained on 80% of images (stratified by content category where available) and evaluated on a held-out 20% test set; generalization was indexed by test-set R^2. Cross-validated R^2 on the training set served as an overfitting diagnostic. Variable importance was derived from Random Forest using caret's scaled importance metric.

Individual differences in affective ratings were analyzed using two complementary approaches. For demographic predictors (mean-centred age, binary sex, geographic region [7 levels], and mean-centred absolute latitude), linear mixed-effects models were fitted at the rating level with crossed random intercepts for participant and image (lme4; Satterthwaite approximation via lmerTest), yielding marginal and conditional R^2 via the Nakagawa–Schielzeth method. Regional differences in participant-level mean ratings (averaged across all rated images per person) were additionally tested with one-way ANOVAs, with effect sizes reported as η^2. Sex differences were characterized as Cohen's d from independent-samples t-tests on participant means. Associations between absolute latitude and participant-level mean ratings were estimated as Pearson correlations. These analyses used the same three-item ST Index defined above (mean of awe, connectedness, and gratitude; compassion excluded).

Additional analyses are reported in the Supplementary Materials (available on OSF).

Results

Database Composition, Reliability, and Affective Coverage

Image-level normative means, distributions, and reliability indices are shown in Table 1 and Figs. 1–2. Valence showed the broadest distribution ($M = 5.86$, $SD = 1.46$; range 1.47–8.28), confirming that the database spans the full pleasant–unpleasant continuum, together with the strongest image-level reliability ($ICC_{image} = .40$). Arousal, in striking contrast, was markedly compressed ($M = 4.74$, $SD = 0.61$) and showed near-zero image-level reliability ($ICC_{image} = .04$) alongside high rater-level variance ($ICC_{person} = .27$): in nature imagery, activation is primarily a property of the person, not the stimulus — consistent with restorative-environment theory, which holds that natural scenes broadly reduce arousal regardless of content. The four self-transcendent dimensions clustered above the scale midpoint (means 5.25–5.43) with intermediate image-level ICCs (.11–.20) and notable rater-level components (.23–.31). Internal consistency was high (mean Cronbach's $\alpha = .83$; 92.9% of stimuli exceeded $\alpha = .70$), and split-half reliability was high to excellent (valence $r = .98$, ST Index $r = .97$, compassion $r = .95$, arousal $r = .87$). Fifty-four percent of images occupied the high-valence/low-arousal quadrant, and content category explained large proportions of affective variance (valence $\eta^2 = .451$; ST Index $\eta^2 = .366$; arousal $\eta^2 = .137$; all $p < .001$), with environmental-issue images producing the lowest valence and highest compassion — a combination absent from databases restricted to pleasant imagery. The ICC asymmetry between valence and arousal recurs across every subsequent analysis as a structural signature of affective responding to nature.

Table 1
Normative Statistics and Inter-Rater Reliability for the Six Affective Dimensions

Dimension	M	SD	Range	ICC_{image}	ICC_{person}
Valence	5.86	1.46	1.47–8.28	.40	.11
Arousal	4.74	0.61	2.87–6.84	.04	.27
Awe	5.36	1.06	2.04–7.90	.18	.23
Compassion	5.25	0.85	2.42–7.66	.11	.31
Connectedness	5.37	1.00	2.07–7.56	.17	.26
Gratitude	5.43	1.09	1.72–7.59	.20	.27

Note. *M and SD refer to image-level normative means on the 1–9 rating scale.* ICC_{image} *= proportion of total variance attributable to systematic between-image differences;* ICC_{person} *= proportion attributable to stable between-rater differences, estimated from cross-classified multilevel models.*

Affective Structure: A Three-Factor Solution

PCA of image-level means yielded a three-component solution explaining 99.7% of variance (Fig. 3A, 3E). PC1 (69.0%) loaded strongly on valence (.99), gratitude (.98), connectedness (.89), and awe (.85), defining a Positive Transcendence dimension. PC2 (19.5%) was defined solely by arousal (1.01) and was orthogonal to the transcendence cluster, consistent with the ICC evidence that arousal operates independently. PC3 (~ 11%) was defined by compassion (1.01), partially independent of both. EFA confirmed this structure: ML1 subsumed valence, awe, gratitude, and connectedness, ML2 isolated arousal, and ML3 isolated compassion (Fig. 3B).

The partial independence of compassion is theoretically significant: it is the one self-transcendent emotion that does not require positive appraisal, being activatable by suffering or degraded landscapes (Stellar et al., 2017). The Gaussian Graphical Model formalised this. Despite a zero-order correlation of $r = .87$, valence and connectedness shared near-zero partial correlation after conditioning on gratitude and awe (partial $r = .008$), showing their association is entirely mediated by the positive-transcendence network (S. Epskamp & Fried, 2018). By contrast, the awe–compassion edge reversed sign (zero-order positive → partial negative), reflecting suppression: images high in awe-relevant qualities tend to be low in the distress-eliciting properties that drive compassion. Gratitude was the most central node (Strength = 1.573) and valence the primary bridge to arousal (Betweenness = 4).

Image Profiles: Four Affective Clusters

Hierarchical cluster analysis (Ward D2, $k = 4$) identified four functionally coherent profiles (Table 2; Fig. 3C–E). The *High Transcendence* cluster ($n = 1,429$, 45.2%; landscapes and animals) showed the highest ratings across all positive dimensions ($M_{valence} = 6.94$, $M_{awe} = 6.23$). The *Moderate Positive* cluster ($n = 1,186$, 37.5%) showed a similar profile at lower intensity. The *Negative-Neutral* cluster ($n = 384$, 12.1%; a mix of built-environment and negatively valenced nature imagery) showed uniformly low ratings. Most informative was the *Distress-Compassion* cluster ($n = 162$, 5.1%; environmental-issue imagery), which combined strongly negative valence ($M = 3.72$) with high compassion ($M = 6.30$), exceeding the compassion means of both positive clusters. In valence-arousal space, *Distress-Compassion* and *Negative-Neutral* images are indistinguishable; in valence-compassion space they are cleanly separated by a large effect ($d = 2.98$). Negative valence alone thus cannot distinguish prosocial concern from generic disengagement. Although *Distress-Compassion* arousal was modestly elevated ($M = 5.38$ vs. overall 4.74), the *Negative-Neutral* cluster showed comparable arousal ($M = 4.92$) without elevated compassion, confirming the heightened compassion is not an artefact of activation.

Table 2
Image Profiles

Affective Cluster	n	Valence	Arousal	Awe	Compassion	Connectedness	Gratitude
High Transcendence	1429	6.94	4.9	6.23	5.78	6.18	6.3
Moderate Positive	1186	5.59	4.41	4.99	4.83	5.02	5.12
Distress-Compassion	162	3.72	5.38	4.49	6.3	4.95	4.68
Negative-Neutral	384	3.28	4.92	3.64	4.18	3.6	3.44

Note. *Mean Ratings on valence, arousal, awe, compassion, connectedness and gratitude depending on affective cluster.*

Semantic Content Dominates Visual Features

To test whether emotional responses are driven by perceptual properties or higher-order content, we decomposed image-level variance into three hierarchical predictor sets (Table 3; Fig. 4A). Low-level visual features explained 8–13% of variance in valence, compassion, and the ST Index — reliable but substantially outperformed at every step. Adding five AI-derived scene-composition features produced large increments ($\Delta R^2 = .073$ valence, .074 compassion, .108 ST Index). Adding the 21 content-category labels raised R^2 to .506 (valence), .318 (compassion), and .438 (ST Index), with category increments ($\Delta R^2 = .20–.31$) three to four times larger than those from any feature set: roughly half the explained variance in how a nature image is felt lies in its categorical identity rather than its pixel statistics. Arousal remained poorly predicted throughout (best $R^2 = .038$), replicating its near-zero ICC. Dominance analysis showed that the predictors of hedonic and activational responding are largely non-overlapping: saturation and spectral power dominated valence (28.97% and 24.87% of explained variance), whereas the colour channels dominated arousal (Fig. 4B).

Table 3
Variance Decomposition and Predictive Accuracy Across Hierarchical Predictor Sets

Outcome	Visual R^2	+ Semantic R^2	+ Categories R^2	RF Test R^2	Ceiling gap
Valence	.114	.187	.506	.281	.225
Compassion	.089	.163	.318	.127	.191
ST Index	.126	.234	.438	.326	.112
Arousal	.027	.038	—	.085	—

Note. *Visual = 9 low-level visual features. + Semantic = model adding 5 AI-derived scene composition features. + Categories = full hierarchical model adding 21 fine-grained content category dummy codes. RF Test R^2 = Random Forest on combined 16 features evaluated on held-out 20% test set ($N \approx 632$ images); this represents the ceiling of fully automated prediction. Ceiling gap = difference between full hierarchical R^2 and RF Test R^2, representing variance recoverable only through object-level semantic recognition. Arousal full model $R^2 = .038$ (visual + semantic only); + Categories and ceiling gap not applicable. ST Index = mean of awe, connectedness, and gratitude. Of Note*: Two of the eleven low-level visual features were automatically excluded from the dominance and hierarchical variance analyses due to near-perfect collinearity with other luminance-based descriptors (rank-deficient design matrix), leaving nine linearly independent features.

Human Infrastructure as the Dominant Predictor

Dominance analysis identified infrastructure ratio — the proportion of each image occupied by human-built structures — as by far the strongest predictor of compassion (71.2% of explained variance), and the dominant predictor of valence suppression (43.8%) and the ST Index (52.4%). Human-coded ratings confirmed this: self-transcendent responding decreased monotonically as human presence increased, $F(3, 3157) = 247.91$, $\eta^2 = .191$, $p < .001$. The suppression was specific to self-transcendent and hedonic dimensions — large for valence ($\eta^2 = .164$), moderate for compassion ($\eta^2 = .040$), negligible for arousal ($\eta^2 = .007$) — confirming a targeted suppression of transcendent affect rather than generic negative affect. Vegetation ratio was the second strongest predictor of valence (34.7%) and ST Index (18.4%), while water ratio showed disproportionate importance for the ST Index (17.6%) relative to valence (10.7%), suggesting water specifically amplifies self-transcendent responding beyond its hedonic contribution.

Automated Prediction Approaches but Does Not Reach the Human Recognition Ceiling

Random Forest models on the combined feature set achieved held-out test $R^2 = .281$ (valence), .127 (compassion), and .326 (ST Index), outperforming elastic net and linear regression by 32–47% (Fig. 5A). Test R^2 matched or exceeded cross-validation R^2 ($|CV - test| \leq .04$), confirming stable generalisation without overfitting; the best model predicts the ST Index of an unseen image to within RMSE = 0.86 scale points. Arousal remained poorly predicted (best $R^2 = .085$). A persistent ceiling gap remained between automated predictions and the full hierarchical model (.225 valence, .191 compassion, .112 ST Index) — variance recoverable only when a rater recognises what an image shows. Feature-importance rankings produced a complete inversion between arousal and all self-transcendent outcomes (Fig. 5B, 5C):

infrastructure ratio ranked first for valence, compassion, and ST Index (normalised importance = 100, all others below 47) but dropped to 68.4 for arousal, where the red channel (100), edge complexity (93), and colour temperature (90) led instead. Self-transcendent outcomes are driven by semantic scene content; arousal by low-level perceptual intensity.

Cultural and Demographic Moderators

Mixed-effects models (random intercept for image) revealed a consistent pattern: rater-level effects were small for valence and substantially larger for self-transcendent dimensions, mirroring the ICC pattern and the three-factor structure. Regional differences were significant across all outcomes (all $p < .001$) but smallest for valence ($\eta^2 = .025$) and moderate for arousal ($\eta^2 = .076$), gratitude ($\eta^2 = .075$), and compassion ($\eta^2 = .072$); African raters scored consistently higher than European raters on self-transcendent dimensions, with only a modest valence advantage (Fig. 6a). Across all regions the rank ordering of emotions was preserved — arousal lowest, gratitude and connectedness highest — indicating that regional differences modulate the level of responding without altering its structure. The hemisphere effect was continuous rather than discrete: absolute latitude correlated negatively with all six emotions (all $p < .001$; Fig. 6c), most strongly for gratitude ($r = -.227$) and compassion ($r = -.216$), most weakly for valence ($r = -.131$), and persisted for the social-relational emotions after controlling for region. Female raters showed higher responding across all self-transcendent and activational dimensions — largest for awe ($d = -0.15$) — while valence showed no sex difference ($d = -0.02$, $p = .68$). Age effects were negligible (all $|r| < .082$). Critically, stimulus-level variation dominated rater-level variation by an order of magnitude: content-category effects ($\eta^2 = .14$–$.45$) exceeded even the largest demographic effect (hemisphere × arousal, $d \approx 0.43$) by roughly tenfold, supporting the validity of E2IATLAS pooled normative means; region-stratified norms are available on OSF for cross-cultural precision.

Discussion

E2IATLAS is, to our knowledge, the first normative database to jointly characterise hedonic and self-transcendent responding to nature imagery at scale, pairing six-dimensional norms with visual feature data and AI-derived semantic descriptors across a global sample. Four findings emerge: a three-factor affective structure that challenges the sufficiency of the valence-arousal circumplex; four image profiles spanning the full eco-emotional range; a clear hierarchy in which semantic content dominates visual features as a predictor of self-transcendent responding; and a cross-cultural pattern distinguishing the near-universality of hedonic valence from the systematic modulation of self-transcendent emotions.

A Three-Factor Affective Structure: Beyond Valence and Arousal

The dominant theoretical framework for affective stimuli has long been the two-dimensional circumplex model of valence and arousal (Russell, 1980). The present data indicate that this framework is insufficient for capturing the full affective signature of nature imagery. PCA and EFA converge on a three-factor solution: a *Positive Transcendence* factor uniting valence, awe, gratitude, and connectedness constitutes the dominant axis (69.0% of variance); a largely orthogonal *Activation* factor is defined exclusively by arousal; and a *Compassion* factor is partially independent of both. The co-emergence of valence with the self-transcendent cluster is a theoretically important finding in its own right. It confirms, at the stimulus level, what experimental paradigms have established at the manipulation level: the same images that are awe-inspiring tend to be deeply connecting and gratitude-eliciting because they share a class of semantic content — vast, living, unbounded natural scenes that trigger the small-self mechanism (Piff et al., 2015; Song, 2023; Stellar et al., 2017). This confirms the construct validity of a composite ST Index as a psychometrically sound screening criterion for selecting stimuli that jointly engage restorative and self-transcendent response systems (Jacobs & McConnell, 2022).

The largely orthogonal Activation factor is equally informative. The near-zero image-level ICC for arousal — indicating that activation is primarily a property of the rater rather than the stimulus in nature imagery — is consistent with restorative environment theory (S. Kaplan, 1995; Ulrich, 1983), which proposes that natural scenes broadly reduce physiological arousal as a class. That arousal nevertheless constitutes a distinct, orthogonal factor reflects consistent rater-level variability in how activating participants find nature stimuli, independent of content. This has a direct practical implication: arousal-matched stimulus selection based on image-level normative means will be unreliable, and visual feature proxies (colour temperature, edge complexity) may serve as better selection criteria for this dimension.

The partial independence of compassion from the positive-transcendence cluster is the most theoretically novel structural finding. Compassion is the one STE in the battery that does not require positive appraisal — it can be activated by perceived suffering, environmental destruction, or degraded landscapes (Goetz et al., 2010; Stellar et al., 2017). The Gaussian Graphical Model makes this structural independence visible: within the positive-transcendence cluster, strong zero-order associations collapse to near-zero partial correlations once the shared network is conditioned out (e.g., valence–connectedness partial $r = .008$), whereas the awe–compassion edge reverses sign relative to its zero-order correlation, reflecting suppression — images highest in awe-eliciting properties tend to be lowest in the distress-eliciting properties that drive compassion. This mirrors a fundamental theoretical distinction: awe expands the self outward toward vastness and connection (Keltner & Haidt, 2003; Song, 2023), while compassion directs concern toward a specific perceived other in need (Goetz et al., 2010). Both are self-transcendent and prosocial, but they operate through different motivational pathways, with different implications for the pro-environmental behaviours they predict (Castelo et al., 2021; Ichwana et al., 2025; Jacobs & McConnell, 2022). The structural dissociation between them is thus empirically consequential for environmental psychology: it warrants treating awe-based and compassion-based pathways as distinct targets for experimental investigation rather than as interchangeable facets of a unitary STE construct.

Four Image Profiles and the Distress-Compassion Profile

The *High Transcendence* and *Moderate Positive* profiles together account for over 80% of the database, confirming that positive self-transcendent affect is the dominant emotional signature of nature imagery, and E2IATLAS samples it more broadly and more diversely than prior resources. The two remaining profiles map territory prior databases have not characterised. The *Negative-Neutral* profile — built-environment and negatively valenced nature imagery rated low across all dimensions — occupies the region circumplex models predict for unpleasant stimuli. The *Distress-Compassion* profile, by contrast, reveals a functionally distinct response invisible to hedonic frameworks: strongly negative valence with elevated compassion, concentrated in environmental-issue imagery. The two are indistinguishable in valence-arousal space but cleanly separated in valence-compassion space (d = 2.98). A circumplex-only assessment would misclassify *Distress-Compassion* as equivalent to neutral-negative built imagery, obscuring what is plausibly the most motivationally distinct response in the database.

For conservation communication, this profile offers a path toward a longstanding puzzle: images of environmental degradation show inconsistent motivational effects, sometimes increasing engagement, sometimes producing numbness (Leviston et al., 2014; Liu et al., 2025; Wang, 2019). The present data suggest this inconsistency may partly reflect variation in the compassion content of stimuli — a dimension invisible to researchers measuring only valence and arousal. Images high in *Distress-Compassion* may reliably motivate prosocial concern, whereas negative but low-compassion images may produce disengagement. This hypothesis is now directly testable using E2IATLAS compassion norms, a design previously impossible.

Semantic Content as the Primary Driver of Self-Transcendent Responding

What a nature image depicts determines how it is felt to a far greater degree than how it appears at the visual level. Content-category labels account for the dominant share of variance in valence and all self-transcendent dimensions, outweighing both low-level visual features and AI-derived scene proportions. This extends prior work on recognisable content in affective evaluation (Castelhano & Williams, 2021; Mikels et al., 2005) to the self-transcendent domain, with a direct implication for neuroimaging: visual feature matching between categories is insufficient to control for self-transcendent differences even when perceptual parameters are equalised.

Infrastructure ratio — the proportion of each image occupied by human-built structures — emerges as the single dominant predictor across all self-transcendent and hedonic outcomes, providing a quantitative account of why human-modified environments reduce self-transcendent responding: they suppress the semantic conditions under which the small-self mechanism is triggered. The gradient from pristine to human-dominated environments maps onto a monotonic decrease in the ST Index, and the suppression is specific to self-transcendent and hedonic dimensions while leaving arousal unaffected — indicating a targeted rather than generic mechanism. Water content showed disproportionate importance for the ST Index relative to valence, consistent with blue-space restoration research (Bratman et al., 2015; Sudimac et al., 2022; White et al., 2019) and awe induction using vast aquatic scenes (Chirico et al., 2023; Chirico, 2017). The ceiling gap between automated prediction and full categorical recognition confirms that human normative ratings capture semantic information unavailable from features alone, identifying a target for future computational work using deep-network embeddings of object identity and scene semantics.

Cross-Cultural Universality and Differentiation

The individual-difference pattern is coherent and practically important for stimulus norming. Hedonic valence showed the smallest regional differences, consistent with evolutionary accounts predicting pan-human preferences for habitat-typical environments (Ulrich, 1983) — evidence that the basic capacity to find nature pleasant is a species-wide default relatively impervious to cultural mediation, validating pooled valence norms. Self-transcendent dimensions showed moderate regional effects: African raters reported higher awe, connectedness, and gratitude than European raters, consistent with research on collectivistic value orientations and interdependent self-construal as moderators of self-transcendent responding (Markus & Kitayama, 1991; Tam, 2013). Cultures with more porous self–other boundaries may more readily experience boundary-dissolving emotions. Yet the consistent rank ordering of emotions across all regions confirms that the affective structure of nature imagery is culturally invariant even when its intensity is not — a differentiated universality in which basic experiential form is cross-cultural while intensity is shaped by transmitted values and histories of nature contact.

The continuous latitude gradient — a monotonic decrease in all six dimensions with absolute latitude, persisting after controlling for regional grouping — suggests that ecological context contributes to individual differences independently of cultural identity (Mesquita, 2022; Murray et al., 2011). Populations at lower latitudes, with year-round access to biodiverse environments, may develop stronger default orientations toward nature-based awe, connectedness, and gratitude. The sex-difference pattern — female elevation across all self-transcendent and activational dimensions with none in valence — mirrors accounts in which what differs by sex is not the capacity to find nature pleasant but the breadth of other-oriented responding (Jacobs & McConnell, 2022). Across all analyses, stimulus-level variation dominated rater-level variation by an order of magnitude, supporting pooled normative means as robust stimulus descriptors for most applications.

Methodological Contributions & Limitations

E2IATLAS makes four methodological contributions. It is, to our knowledge, the first database to include all four self-transcendent emotions alongside standard hedonic dimensions, enabling direct comparison of their stimulus determinants and moderators within one normed set. Its geographic stratification across more than 50 countries and all five major Köppen–Geiger zones substantially expands the population of inference beyond WEIRD-skewed samples. Its concurrent low-level visual and AI-derived semantic descriptors enable controlled neuroimaging designs in which categories are matched on perceptual dimensions while emotional content varies. And its inclusion of environmental-issue imagery — intentionally absent from prior positive-affect databases — makes it, to our knowledge, the first resource covering the full eco-emotional spectrum, from awe-inspiring grandeur to compassion-eliciting degradation.

Several limitations deserve note. Compassion showed the lowest image-level reliability, so compassion norms should be treated as probabilistic rather than fixed stimulus descriptors; arousal's near-zero image-level reliability means visual feature proxies may complement selection for that dimension. Recruitment via Prolific enables geographic stratification but introduces platform biases: samples tend to be more educated and technologically engaged than population-representative samples, and coverage remains uneven across regions, so region-specific norms should be read as estimates. The analyses treat all ratings as contemporaneous and do not model temporal effects of climate news cycles, which may plausibly shift ratings of environmental-issue imagery (Hickman et al., 2021). Finally, the pool was assembled from existing open-access sources rather than constructed by systematic, theory-driven selection, and is not fully balanced across content categories.

Applications and Future Directions

E2IATLAS supports pre-validated stimulus selection with simultaneous control over valence, the self-transcendent complex, arousal, and visual features — permitting designs in which awe is varied while valence is held constant, or connectedness and gratitude are induced in isolation from compassion. The ST Index serves as a single composite, while per-dimension norms permit parametric designs. In environmental neuroscience, concurrent feature data lets researchers match categories perceptually while varying emotional content. In conservation communication, compassion norms and the ST Index distinguish images likely to motivate prosocial concern from those likely to elicit disengagement, making it possible to experimentally dissociate compassion-based from awe-based pro-environmental pathways (Ichwana et al., 2025; Jacobs & McConnell, 2022, 2024). The latitude gradient motivates cross-cultural replication of STE-to-behaviour pathways using region-stratified stimuli; the dominance of infrastructure ratio provides a foundation for urban-green-space research; and the ceiling gap motivates deep-learning models trained to predict self-transcendent response.

Conclusion

E2IATLAS provides what environmental psychology and affective science have lacked: a large-scale, cross-culturally normed, multidimensionally validated database of nature imagery that captures the full eco-emotional spectrum and pairs affective norms with the visual feature data required for controlled designs. Across all findings, what proves most consequential lies beyond the circumplex: the structure of the self-transcendent affective space, the diversity of pathways through which nature imagery engages prosocial motivation, and the importance of measuring awe, connectedness, gratitude, and compassion as distinct dimensions rather than collapsing them into valence. As the environmental crises motivating this research intensify, the pathways through which images of nature and nature-under-threat engage human motivation become increasingly consequential. E2IATLAS is offered as an open infrastructure for the research needed to understand, and act on, those pathways.

Declarations

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Author Contributions (CRediT)

Carmen Morawetz: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Data Availability Statement

The dataset generated and analysed during the current study are available in the OSF repository: https://osf.io/tz74d.

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Competing Interests

The author has no relevant financial or non-financial interests to disclose.

Research Transparency Statement

Conflicts of interest: The author declares no conflicts of interest. **Artificial intelligence:** AI-assisted technologies were used in a limited capacity in the preparation of this article; specifically, large language model tools (Anthropic's Claude) assisted with language polishing of the manuscript text and with the programming of analysis scripts. All scientific content, interpretations, and conclusions are the sole responsibility of the author. **Ethics:** The study was approved by the Board for Ethical Questions in Science of the University of Innsbruck (Approval No. 90/2022); all participants provided written informed consent. Preregistration: No aspects of this research were preregistered. **Open materials and data:** All rating scales, survey materials, the image category coding scheme, image-level normative means, and visual feature values are publicly archived at https://osf.io/tz74d. A complete list of stimulus images, organised by source database, is archived on OSF; due to licensing restrictions, only images from non-commercially licensed sources are made directly available for download (ChatGPT, Unsplash, Kaboompics, Life of Pix, Climate Visuals), while images from publicly available source databases can be obtained from their respective repositories via links provided on OSF.

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Figures

Figure 1

Database overview: affective distributions and content coverage (N = 3,161 images). (A) Distribution of image-level normative means for all six affective dimensions. Each histogram represents one value per image (mean across ≈50 raters per image), so individual scale-use artefacts are averaged out. Valence shows the broadest distribution (SD = 1.46; range: 1.47–8.28), confirming full affective range coverage. Arousal shows the most compressed distribution (SD = 0.61; range: 2.87–6.84), consistent with the predominantly calming character of natural scenes. Self-transcendent dimensions are moderately right-skewed, reflecting the dominance of positive-valenced nature content. (B) Distribution of affective ratings across super-categories. Box plots show median, IQR, and 1.5× IQR whiskers.

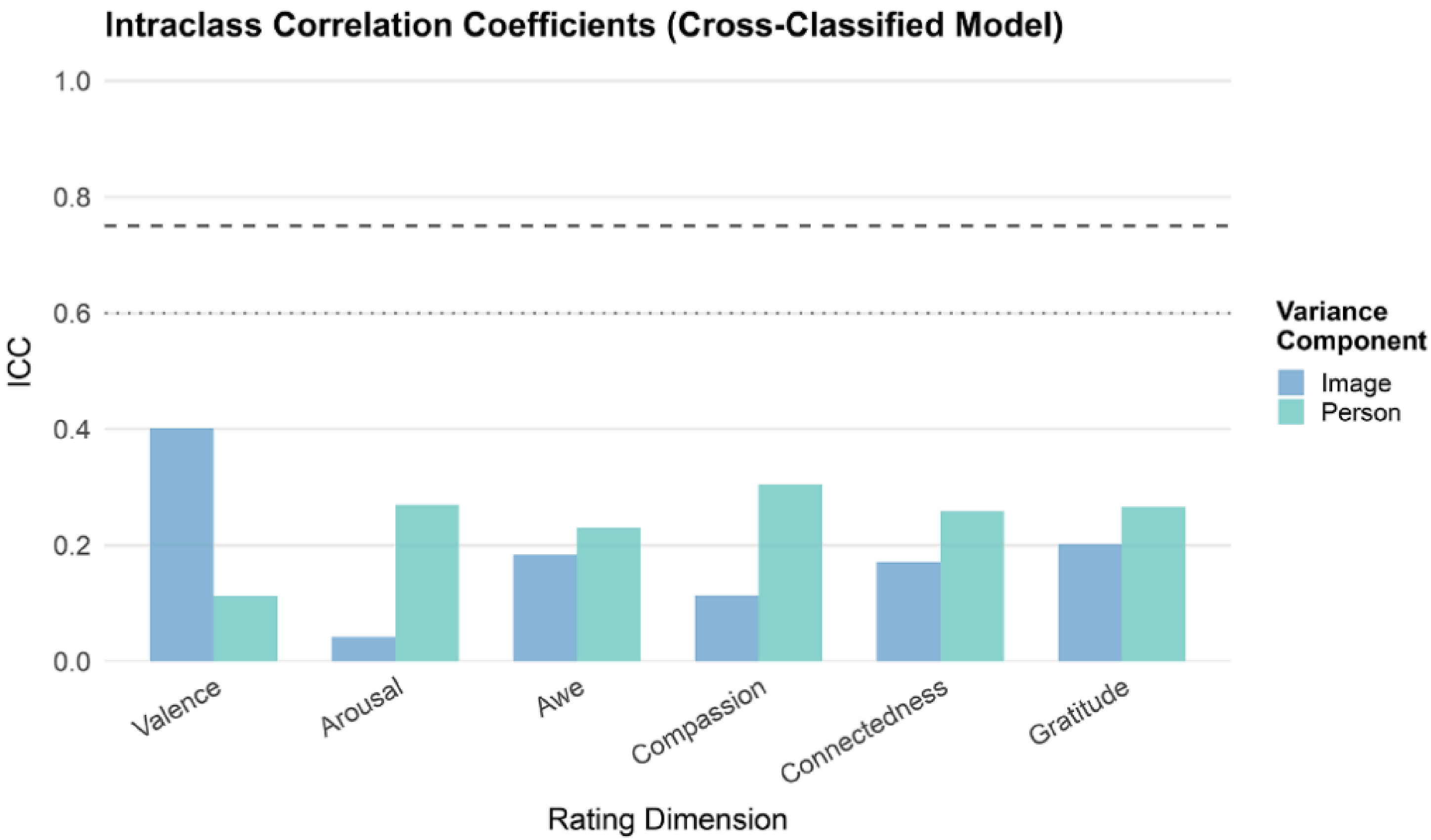

Figure 2

Inter-rater reliability across affective dimensions. ICC_{image} = proportion of total variance attributable to stable between-image differences; ICC_{person} = proportion attributable to stable between-rater differences, estimated from cross-classified multilevel models (lme4). Dashed line: ICC = .75 (threshold for good–excellent reliability). Dotted line: ICC = .60 (threshold for moderate reliability; values below indicate poor reliability).

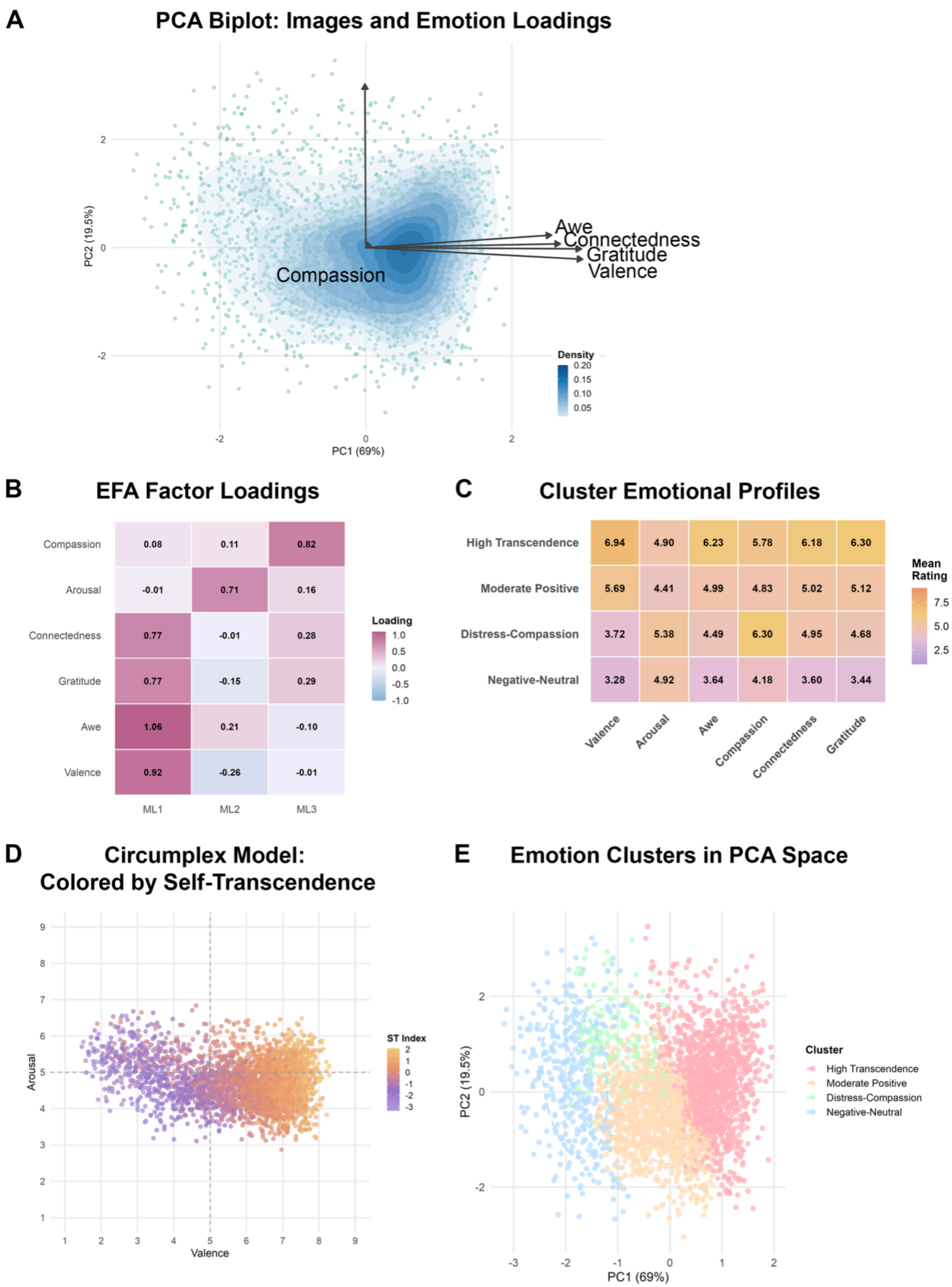

Figure 3

Affective structure of nature imagery. (A) PCA biplot: all 3,161 images as points (density contours) with emotion dimension vectors. PC1 (69.0%) defines a Positive Transcendence axis; PC2 (19.5%) is defined solely by arousal. (B) EFA factor loadings (maximum likelihood, oblimin rotation, 3 factors). ML1 (Positive Transcendence) loads on valence (.92), awe (1.06), gratitude (.77), connectedness (.77). ML2 (Activation) is defined by arousal (.71). ML3 (Compassion) reflects partial factorial independence of prosocial responding (.82). (C) Cluster emotional profiles: mean ratings per cluster across all six affective dimensions (k = 4). (D) All 3,161 images in the valence–arousal circumplex coloured by ST Index (warmer = higher self-transcendence). Self-transcendent affect concentrates in the high-valence/low-arousal quadrant. (E) Four emotion clusters in PCA space (PC1 69%, PC2 19.5%; Ward D2 linkage, k = 4). Each point is one image; colours identify cluster membership.

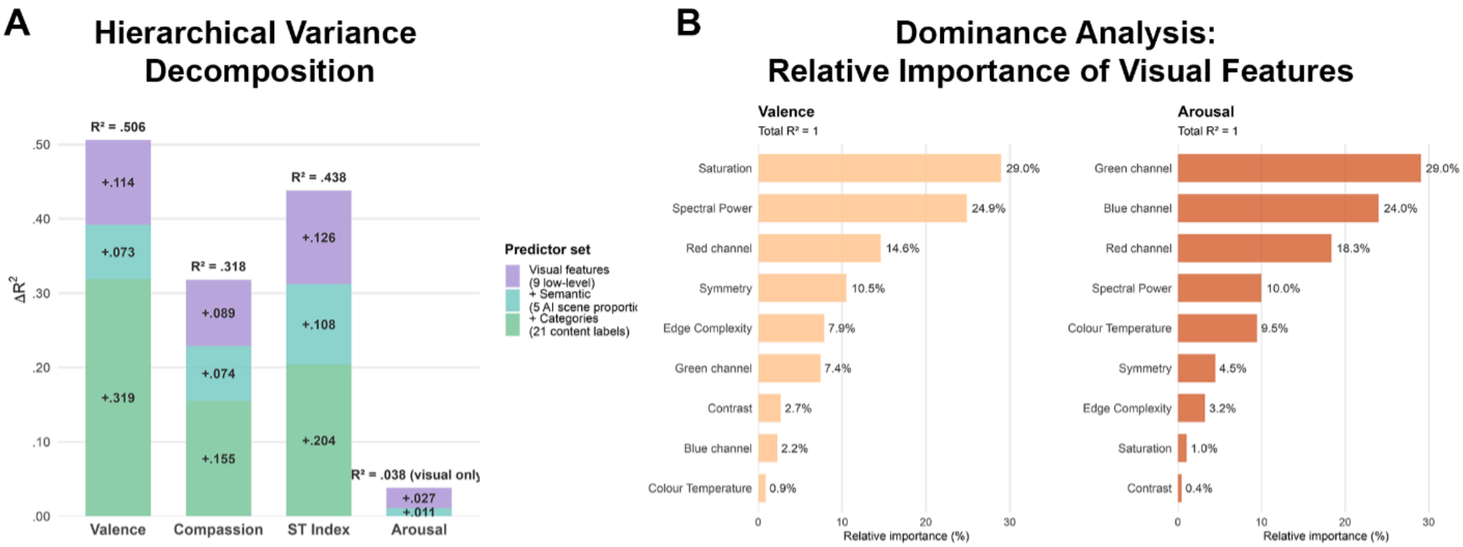

Figure 4

Semantic content dominates visual features in predicting affective responses to nature. (A) Unique variance explained by three hierarchical predictor sets via dominance analysis. Visual: 9 low-level features. Semantic: 5 AI-derived scene proportions (SegFormer-B0). Categories: 21 content category codes. Category labels explain substantially more variance than any feature set. Arousal is poorly predicted throughout (best $R^2 = .038$). (B) Relative importance of visual features for valence and arousal (dominance analysis). Saturation and spectral power dominate for valence; colour channels for arousal. *Of Note*: Two of the eleven low-level visual features were automatically excluded from the dominance and hierarchical variance analyses due to near-perfect collinearity with other luminance-based descriptors (rank-deficient design matrix), leaving nine linearly independent features.

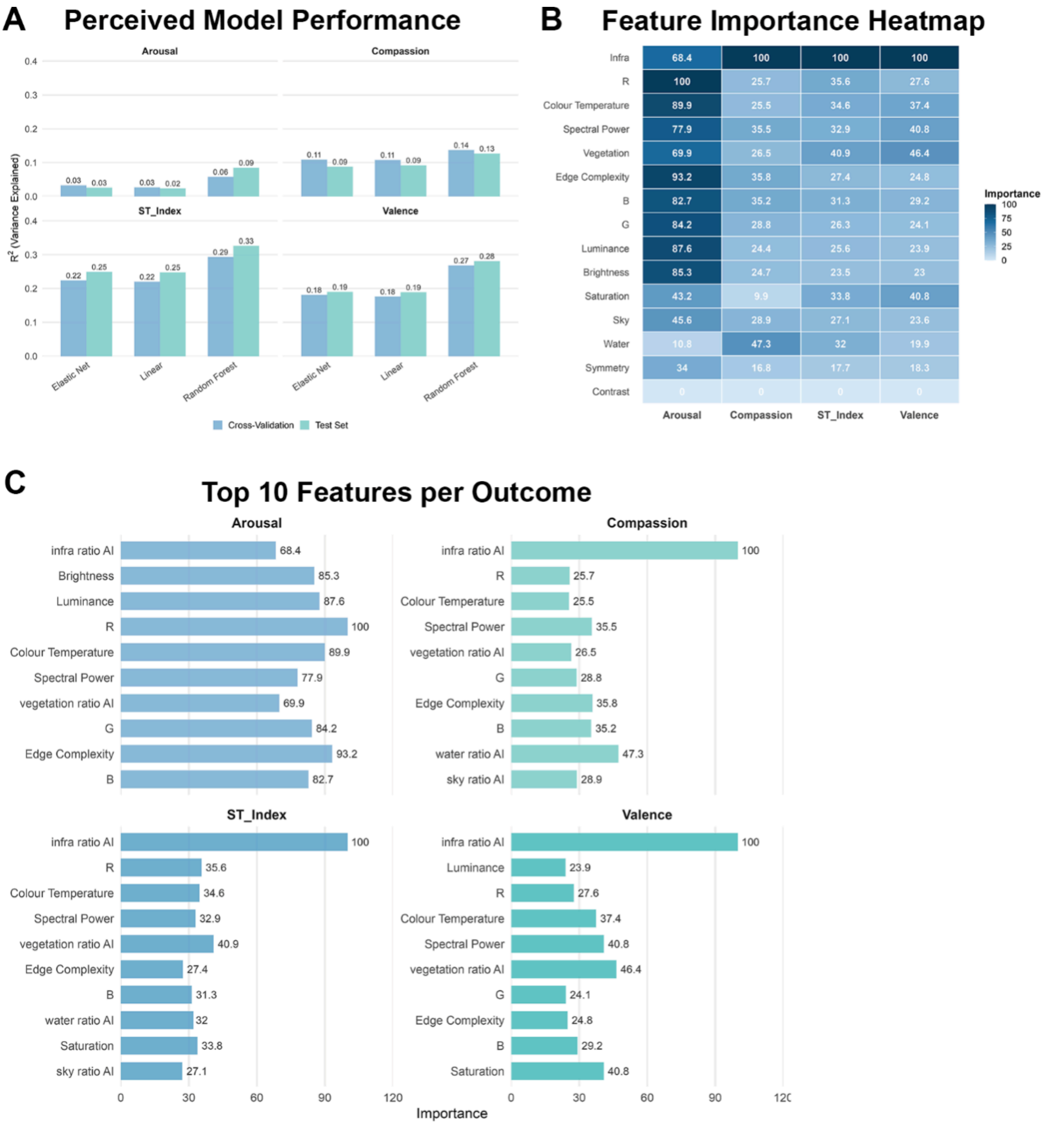

Figure 5

Automated prediction of affective responses to nature images (N = 3,161). (A) Random Forest, Elastic Net, and Linear Regression performance (R^2) via 10-fold cross-validation and held-out 20% test set (N ≈ 625 images). Random Forest outperforms linear models across all outcomes; test R^2 matches or exceeds cross-validation R^2, confirming generalisation without overfitting. Arousal remains poorly predicted across all models (best test R^2 = .085). (B) Random Forest feature importance heatmap (normalised to 100 per outcome). Infrastructure ratio dominates valence, compassion, and ST Index (importance = 100) but drops to 68.4 for arousal, where the red channel (100), edge complexity (93), and colour temperature (90) lead instead. (C) Top 10 features per outcome (bar charts). The dissociation confirms that self-transcendent outcomes are driven by semantic scene content; arousal by low-level perceptual intensity features.

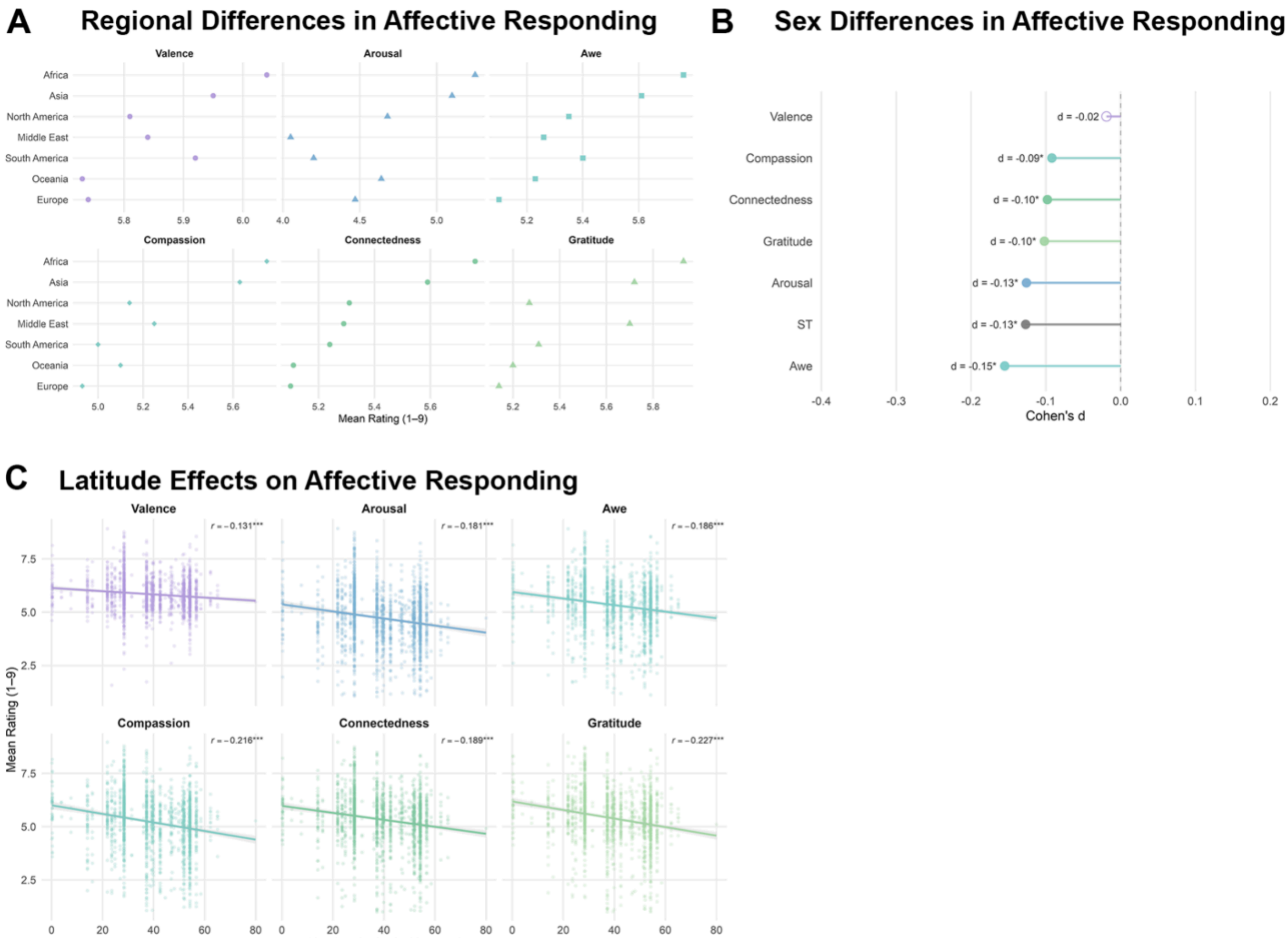

Figure 6

Cultural and demographic moderation of affective responding to nature imagery (N = 1,842 raters with demographic data). (a) Mean ratings across seven world regions (error bars = ±1 SE). Regional differences are moderate for arousal ($\eta^2 = .076$) and gratitude ($\eta^2 = .075$) but small for valence ($\eta^2 = .025$). (b) Cohen's d for sex differences (male − female). All self-transcendent dimensions show significant female elevation; valence is the exception (d = −0.02, n.s.). (c) Rater-level mean ratings as a function of absolute latitude. All correlations are negative; strongest for gratitude (r = −.227), weakest for valence (r = −.131).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- E2IATLASSupplementaryMaterials.pdf