Journal of Environmental Psychology 77 (2021) 101676

Contents lists available at ScienceDirect

Journal of Environmental Psychology

journal homepage: www.elsevier.com/locate/jep

Psychological responses to buildings and natural landscapes

Adam B. Weinberger [a,b,*], Alexander P. Christensen [a], Alexander Coburn [a,c], Anjan Chatterjee [a]

[a] Penn Center for Neuroaesthetics, University of Pennsylvania, USA
[b] Department of Psychology, Georgetown University, USA
[c] School of Medicine, University of California – San Francisco (UCSF), USA

ARTICLE INFO

Handling Editor: L. McCunn

Keywords:
Aesthetics
Architecture
Environmental psychology
Network science
Exploratory graph analysis

ABSTRACT

People frequently form aesthetic judgements of built and natural environments. Identifying psychological responses induced by one's surroundings – as well as differences across contexts – is necessary to better access salubrious qualities of different natural and built environments. Here, we tested two primary hypotheses about responses to exterior architecture and natural landscapes. First, aesthetic responses to built and natural environments reduce to a few underlying psychological dimensions. Second, we hypothesized greater consistency in aesthetic appraisals to natural than built environments. Using techniques from network science, we found that responses to images of exterior architecture and natural landscapes were derived from three psychological dimensions: Fascination (a scene's richness and interest), Coherence (analytic judgements about a scene's organization and construction), and Hominess (feelings of warmth or coziness). Notably, however, subsequent exploratory analyses indicated some differences in psychological responses across contexts. For example, Hominess was associated with greater naturalness for the built environments, but homier natural landscapes were more ordered. We also found less variability in responses to natural landscapes, consistent with our second hypothesis. Taken together, the present study demonstrates that Fascination, Coherence, and Hominess are broadly applicable aesthetic experiences induced by one's surrounding environment. Moreover, human beings may show more agreement for natural stimuli than for artifacts of human culture.

1. Introduction

Human beings frequently form aesthetic impressions of their environment. Environmental aesthetic qualities affect a wide range of psychophysiological responses (Ellard, 2015), including happiness (MacKerron & Mourato, 2013), stress (Ulrich, 1991, 1993), attention (Berman et al., 2008, 2019; Bowler et al., 2010), creativity (Mehta & Zhu, 2009), memory (Bratman et al., 2019), sleep (Dutton, 2014), and learning (Earthman, 2004). Our goal in this study is to clarify underlying psychological dimensions of aesthetic responses to the environment, and to identify differences in such responses across contexts. This research may provide a means to better assess how different environments enhance health and wellness.

Investigations of the correspondence between the physical properties of a space and the psychological responses they instantiate hark back to Aristotle, who asserted the value of "material" causes – characteristics of substrates that give rise to human responses (Killeen, 2001). More recently, researchers of empirical aesthetics have sought to identify universal or domain-general laws that determine individuals' aesthetic experiences that generalize across contexts (Martindale, 1990), although most also acknowledge the importance of stimulus-dependent contextual features (Bullot & Reber, 2013; Chatterjee & Vartanian, 2016; Nadal & Chatterjee, 2019). Indeed, the notion of contextual differences in aesthetics has also been long-postulated. Immanuel Kant, for instance, proposed that beautiful natural objects appear as if they were created for a specific purpose, but human-made objects appear most beautiful if they look natural (Kant, 1790).

We recently outlined a model of architectural experience (Coburn et al., 2017), drawing from an existing model of aesthetic experience broadly, the aesthetic triad (Chatterjee & Vartanian, 2014). According to the aesthetic triad, aesthetic experiences are an emergent mental state stemming from interactions between three large-scale sensory-motor, emotion-valuation, and knowledge-meaning neural systems.

The sensory-motor system is engaged for bottom-up processing of any sensory modality such as the visual, tactile, auditory, and olfactory features of a stimulus. Across many experimental conditions, aesthetic appraisals activate brain regions specialized for primary and higher order sensations and perception (Brown et al., 2011; Vartanian & Skov,

* Corresponding author. 3710 Hamilton Walk, Philadelphia, PA, 19104, USA.
E-mail address: adam.weinberger@pennmedicine.upenn.edu (A.B. Weinberger).

https://doi.org/10.1016/j.jenvp.2021.101676
Received 26 June 2021; Received in revised form 13 August 2021; Accepted 19 August 2021
Available online 20 August 2021

2014), as well as brain networks engaged for motor responses (Gallese & Freedberg, 2007; Humphries et al., 2021; Thakral et al., 2012). In the case of architectural or environmental aesthetics specifically, sensory features of an environment instantiate interest and a desire to explore or approach a given space (i.e., behavioral-motivational responses; Coburn et al., 2017). This link is consistent with longstanding accounts in cognitive science that postulate associations between perception and motivation (Day, 1967) and attention (James, 1985; Kaplan, 1995; Reber et al., 2004), as well as perspectives from environmental psychology that propose that evolutionarily-beneficial environments automatically capture human interest (Bowler et al., 2010; Joye, 2007; Ulrich, 1993). Specific visual properties of the environment elicit activation of temporal lobe regions sensitive to visual motion (Vartanian et al., 2015) and the globus pallidus, a brain structure responsible for regulating voluntary movement (Vartanian et al., 2013), further evidence for this association between environmental visual features and behavioral-motivational responses.

Along with the activation of sensory-motor brain regions, aesthetic experiences consistently engage neural structures involved in emotion and reward processing (Barrett et al., 2007; Freedberg & Gallese, 2007). That is, aesthetic appraisals evoke strong affective responses, underscoring the role of the emotion-valuation system. Valence – how an object or space makes one feel – is a commonly studied affective response in empirical aesthetics that has been examined across domains and contexts (Leder et al., 2004). Similarly, researchers have asked the extent to which a specific object makes observes feel uplifted or stimulated (Böhme, 1993; Evans, 2003; Graham et al., 2015). A host of emotional responses relate specifically to environmental aesthetics. For instance, built environments and natural landscapes are thought to elicit deeply human emotions (Alexander, 1977; Bachelard, 2014), such as feelings of warmth, relaxation, hominess, and comfort.

Lastly, the knowledge-meaning system of the aesthetic triad is associated with putatively top-down influences on experiences (Chatterjee & Vartanian, 2014, 2016). For example, viewers of artwork prefer originals to copies (Newman & Bloom, 2012) and have more favorable impressions if they have prior knowledge about an artwork's meaning (Coburn et al., 2017; Kirk et al., 2009; Leder, 2013). That is, aesthetic experiences may vary across individuals based on an observer's ideas about different kinds of objects or spaces. The effects of individual differences, however, may be less pronounced for natural aesthetic domains; people show more agreement when asked to rate the aesthetic value of naturally-occurring stimuli (e.g., human faces and natural landscapes) than for human artifacts (e.g., artwork and architecture; Vessel et al., 2018). Greater consistency in preference for natural landscapes align with "biophilic" accounts (Joye, 2007; Ulrich, 1993) that describe evolved, seemingly innate preferences for naturally-occurring shapes and forms.

Crucially, all three systems need not be engaged in equal measure. Some stimuli may preferentially engage one system over another. Further, the delineation between the three systems is loose; many of the previously described psychological responses – e.g., desire to explore a space, feelings of warmth – stem from a combination of neurocognitive processes. Processing fluency theories (Reber et al., 2004) indicate that aesthetic experiences arise when one is able to easily process the properties of an object. Objects that are fluently processed are hedonically experienced and require fewer attention resources, leading to stress reduction and improved affect. Thus, on this account, the sensory-motor system (which processes object properties) is intertwined with both the knowledge-meaning system (familiar objects may be more fluently processes) and the emotion-valuation system (which indicates valence and stress).

The nature of these cross-system interactions – and the psychological states elicited by them – are also likely to vary across contexts. This sentiment is evident in Kant's aforementioned perspective on beauty; properties that individuals deem aesthetically pleasing differ for natural and built objects. This discrepancy may stem from differential weighting of specific stimulus features (Vessel et al., 2018), leading to differences in recognition, understanding, processing fluency, and, ultimately, aesthetic experiences (Berman et al., 2019; Coburn et al., 2019; Oostendorp & Berlyne, 1978; Reber et al., 2004). That is, the interaction between certain qualities and the psychological responses they produce may not be the same for built and natural environments. Aesthetic experiences may also diverge across architectural styles; people prefer strikingly different aesthetic qualities for different rooms of their home (Graham et al., 2015), presumably because each room meets different needs. Thus, the presence of a specific architectural feature in one room may evoke disparate psychological responses to *the same feature* in another room. For example, designs that are bright or attention-grabbing may convey a fun, exciting ambiance in a game room but be experienced as distracting or unpleasant in a study. Further, some psychological responses to the qualities of inhabited spaces might not apply to other objects (e.g., a painting or piece of music may not make observers feel "at home").

Other work on aesthetic experience indicates a distinction between analytic and emotional judgements. Analytic judgements refer to judgements about qualities of the stimulus itself and emotional judgements refer to self-reflective impressions about one's inner state (Chatterjee, 2003; Coburn et al., 2020). Examples of analytic judgements include those formed about visual complexity – the amount of information present in a space (Dosen & Ostwald, 2016) – and organization (i.e., the predictability of visual patterns; Reber et al., 2004). Analytic judgements may be formed independently of other features of the environment (Alexander, 2002; Kaplan & Kaplan, 1989; Mehaffy & Salingaros, 2006), suggesting that the underlying neurocognitive processes may operate similarly across aesthetic domains and contexts (i.e., because it is at least partially independent of other stimulus-specific features). Thus, we wished to identify psychological responses induced by architecture and the natural environment and determine how responses vary across differing contexts.

In one study (Coburn et al., 2020), participants evaluated interior architectural spaces on several aesthetic criteria (Table 1). Using data reduction techniques, the authors found that variance in participant responses was explained by three underlying psychological dimensions: Coherence, Fascination, and Hominess. Coherence included analytic judgements (as opposed to emotional responses) about the extent to which a space appeared organized. Fascination (i.e., the extent to which a space is visually rich and invites exploration) may be derived from an interaction between the sensory-motor and emotion-valuation system. Similarly, Hominess – which refers to feelings of warmth or coziness, and included judgements about a space's naturalness – emerges from the sensory-motor system (which is sensitive to natural stimuli) and the emotion-valuation system (which instantiated feelings of comfort). All three dimensions are also subject to top-down influences from the

Table 1
Aesthetic rating criteria.

Criteria	Rating Prompt	Low Anchor	High Anchor
Complexity	This space looks …	Simple	Complex
Order	This space looks …	Disordered	Organized
Natural	This space looks …	Artificial	Natural
Beauty	This space looks …	Ugly	Beautiful
Personalness	This space looks …	Impersonal	Personal
Interest	This space looks …	Boring	Interesting
Modernity	This space looks …	Aged	Modern
Valence	This space makes me feel …	Bad	Good
Stimulation	This space makes me feel …	Bored	Excited
Vitality	This space makes me feel …	Lifeless	Alive
Comfort	This space makes me feel …	Uncomfortable	Comfortable
Relaxation	This space makes me feel …	Stressed	Relaxed
Hominess	This space makes me feel …	Alienated	At home
Uplift	This space makes me feel …	Diminished	Uplifted
Approachability	If I saw this space, I'd …	Leave it	Enter it
Explorability	If I saw this space, I'd …	Ignore it	Explore it

knowledge-meaning system.

Coherence and Fascination have clear corollaries in other domains of aesthetic experience. Reber's (2004) theory of processing fluency, for example, suggests that complex, fascinating images comprised of smaller, repeating units that can be grouped together (i.e., organized) by the visual system are aesthetically pleasing. Analytic appraisals of coherence influence human responses to paintings (Palmer et al., 2013), landscapes (Kaplan & Kaplan, 1989; Kaplan et al., 1972), and sculptures (Dio et al., 2007). Similarly, fascination has been linked with a range of aesthetic experiences (Berlyne, 1963, 1970; Silvia, 2005, 2008). Others (Kaplan & Kaplan, 1989; Kaplan, 1995; Kaplan et al., 1972) argue that preferences for outdoor landscapes are based on the observers' understanding of "what is going on" (i.e., coherence) as well as their desire to explore the space (fascination). Notably, hominess has been largely ignored in discussions of preferences for outdoor, natural spaces. This absence is somewhat surprising given people's robust preferences for natural settings (Chang et al., 2020; Kaplan, 1995), and the frequency with which architects and designers incorporate "biophilic" (i.e., nature-like) components into the built environment (Abboushi et al., 2019; Joye, 2007; Taylor, 2021; Ulrich, 1993). We are unaware of prior work in any other domains of aesthetics research that has explicitly described hominess as an underlying psychological response. Whether the hominess dimension generalizes to exterior architecture or natural landscapes remains an open question.

Another outstanding issue is that the set of stimuli used by Coburn et al. (2020) were curated; all of the images of interior spaces were previously rated by architects on a small number of visual features. This approach is common in aesthetics experiments designed to consider the effects of specific variables (e.g., curvature, ceiling height, lighting). Controlling images along these variables allows experimenters to mitigate the effects of other potentially confounding stimulus features. The drawback of this strategy, however, is generalizability. That is, do psychological responses identified from a set of constrained images also apply in less controlled images and, of course, in the real world? Because conclusions drawn from carefully controlled images may not generalize to real-world responses (Snow & Culham, 2021), we elected to use more natural stimuli in studying responses to buildings and landscapes.

Here, we applied network-based analyses to test the hypothesis that aesthetic responses to images of exterior architecture and natural landscapes reduce to a few broad yet interconnected underlying psychological dimensions. More specifically, we predicted that responses would be derived from feelings of fascination, coherence, and hominess. We further hypothesized that humans are more consistent in their aesthetic responses to natural environments than to built environments. Thus, we predicted that participants would show more agreement on the aesthetic qualities of natural landscapes than exterior architecture. Additional exploratory questions concerned differences in the underlying psychological dimensions between natural and built environments.

2. Method

2.1. Participants

Two hundred and seventy-five participants completed the study online through Amazon Mechanical Turk. Sample size was based on recommendations for data reduction analyses (Mundfrom et al., 2005). Specifically, Mundfrom and colleagues recommend a sample size of 220 participants for excellent-level criterion (0.98) to detect a 3-factor solution with a low level of communality between the observation variables. Participants provided informed consent, and all study procedures were approved by the University of Pennsylvania IRB. Average study duration was 32.09 min ($SD = 13.37$ min), and participants were paid $6.00 for their time. Following careful quality control of participant data (see Supplementary Information), the final sample consisted of 253 participants ($M_{age} = 37.80$ years, $SD = 10.40$ years; 57.71% male, 41.11% female; see Supplementary Information for exploratory analyses of gender effects on aesthetic experience). All elements of the study design, analytic methods, hypotheses, and predicted results were pre-registered on the Open Science Framework prior to data collection (https://osf.io/a3k7x/).

2.2. Materials and procedures

Stimuli for this experiment included 64 images of exterior architecture and 64 images of natural landscapes. The complete image set was created from stimuli used by another research group (Vessel et al., 2018). Each image was further categorized as belonging to one of 16 different subtypes (8 subtypes for exterior architecture, 8 subtypes for natural landscapes; Fig. 1). Image subtypes were designated with input from an architecture student. All participants were randomly assigned one image from each subtype.

The experiment began with a brief slideshow during which participants were presented with each of their 16 randomly-assigned images sequentially. This exposure was designed to familiarize participants with each image, as well as sensitize them to possible differences between the image types. Next, participants rated each image on 16 aesthetic criteria: complexity, order, natural, beauty, personalness, interest, modernity, valence, stimulation, vitality, comfort, relaxation, hominess, uplift, approachability, and explorability (Table 1). Ratings were made using a 7-point continuous sliding Likert scale (1 = low, 7 = high). All 16 criteria were previously used to assess psychological responses to interior architectural spaces (Coburn et al., 2020). In order to minimize task-switching and possible fatigue (Monsell, 2003), participants made a single aesthetic judgment on all 16 images before advancing to the next judgment. The order of the aesthetic judgment – as well as the image presentation within each – was randomized for each participant. After performing all ratings, participants completed a demographic questionnaire.

2.3. Analytic strategy

2.3.1. Mean-minus-one correlation measure

To examine differences in consistency of judgments for architecture and landscape images, we employed a "mean-minus-one" (MM1) correlation measure, adapted from prior work (Vessel et al., 2018) to assess between-subject agreement for both types of images (i.e., exterior architecture, natural landscapes). First, each participant's ratings were correlated with the average ratings of all remaining participants. This process was repeated iteratively for each participant, resulting in a vector of r values in which each value represented the extent to which an individual participant's aesthetic ratings correlated with the aesthetic ratings of the rest of the sample. An r-to-z transformation was performed to reduce bias, and paired t-tests assessed whether between-subject agreement differed for natural landscapes and exterior architecture images. A z-to-r transformation was then applied for ease of interpretation.

2.3.2. Exploratory graph analysis

The application of network science to the study of aesthetics has become increasingly popular in recent years (e.g., Coburn et al., 2020; Hayn-Leichsenring et al., 2020; Specker et al., 2021). Dimension reduction was performed using exploratory graph analysis (EGA), a method to estimate the number of dimensions (represented as "communities") in multivariate data using undirected network models (Golino et al., 2020; Golino & Epskamp, 2017). Recent work indicates that EGA has advantages over more traditional forms of dimension reduction (e.g., Principal Component Analysis; factor analysis) in identifying the number of latent factors underlying multivariate data, especially when observation variables are highly correlated (Golino et al., 2020). EGA was applied using the *EGAnet* package (version 0.9.9; Golino & Christensen, 2021) in R (version 4.0.3; R Core Team, 2021), and results were visualized using the *GGally* (version 2.1.0; Schloerke et al.,

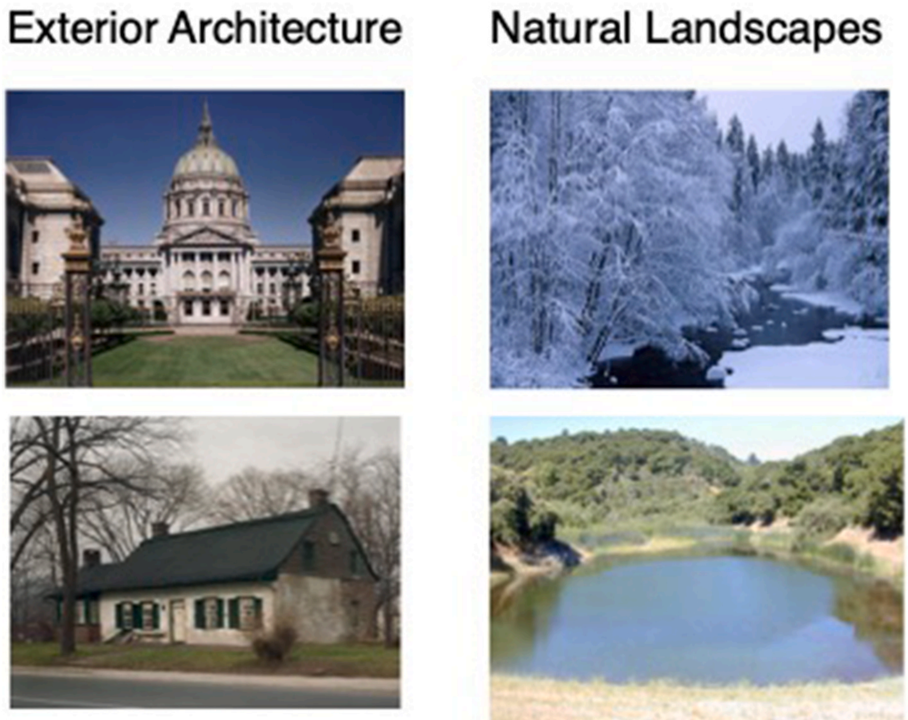

Fig. 1. Example images for exterior architecture and natural landscapes. All participants presented with 8 images of exterior architecture and 8 images of natural landscapes. Each image was classified as belonging to a specific image subtype. Participants were randomly presented with a single image from each subtype. Exterior architecture subtypes: Blocky, Classic/Ornate (example in top left), Colonial, Large House, Modern, Pillared, Simple (example in bottom left), and Misc. Natural landscape subtypes: Beach, Water (example in bottom right), Mountain, Woods, Woods & Water, Plains, Desert, Artic (example in top right). Additional image information available from corresponding author.

2021) and *ggplot2* (version 3.3.3; Wickham, 2020) packages. Details about the implementation of EGA in this study can be found in Supplementary Information.

2.3.3. Addressing redundant variables

Whereas researchers are often forced to (somewhat subjectively) manually remove redundant (i.e., highly collinear) variables in alternative approaches to dimension reduction, we employed a technique known as unique variable analysis (UVA; Christensen et al., 2020). Using a measure called weighted topological overlap (Nowick et al., 2009), a new edge-weight for every edge in the network is calculated based on the weight of all common network neighbors, in turn identifying edge weights that exceed the relative edge weight of other nodes in the network (i.e., indicating redundancy). A reflective latent variable is then created in place of the redundant variables using maximum likelihood with robust standard errors. Creating a latent variable (rather than removing all but one redundant variable) minimizes measurement error and retains all information contained in the original data set (Christensen et al., 2020).

We performed two sets of EGAs (Fig. 2). Because we were primarily interested in comparing the underlying psychological responses for built and natural spaces, EGAs were performed separately for aesthetic ratings of exterior architecture and natural landscapes. Results for these analyses are reported in the order in which they are listed here.

2.3.3.1. EGA 1: overall psychological responses. First, we measured overall psychological responses to exterior architecture and natural landscapes, pooling together and averaging all ratings across all the image subtypes (Fig. 2A). Since the dimensions of these ratings are the aggregate of reactions to all image subtypes, they represent the general structure of responses to exterior architecture and natural landscapes.

2.3.3.2. EGA 2: "agnostic" approach. We performed two additional EGAs (one for exterior architecture, one for natural landscapes) to explore whether rating clusters were driven primarily by the aesthetic criteria (e.g., complexity, beauty) or the different images subtypes (e.g., beaches, forests). This "agnostic" approach was conducted by considering each rating for each image subtype as a unique observation variable (Fig. 2B). That is, networks were estimated using 128 nodes for exterior architecture (8 architecture image subtypes × 16 aesthetic

A

Overall EGA

P	Subtype	Beauty	Order	Uplift
Sub 1	Blocky	3.2	4.0	2.7
Sub 1	Simple	2.0	4.5	3.0
Sub 1	Colonial	2.5	3.0	4.2
Sub 2	Blocky	5.1	1.2	2.0
Sub 2	Simple	1.2	1.0	3.5
Sub 2	Colonial	4.3	6.4	3.2

Data from all image subtypes grouped into single observation variable for each criteria

Examine overall response across different stimuli

Each aesthetic criteria as unique observation variable

B

"Agnostic" EGA

P	Beauty: Blocky	Beauty: Simple	Beauty: Colonial	Order: Blocky	Order: Simple	Order: Colonial	Uplift: Blocky	Uplift: Simple	Uplift: Colonial
Sub 1	3.2	2.0	2.5	4.0	4.5	3.0	2.7	3.0	4.2
Sub 2	5.1	1.2	4.3	1.2	1.0	6.4	2.0	3.5	3.2

Each aesthetic criteria, for each image subtype, as unique observation variable

No assumption of equivalent responding for a single aesthetic criteria across different image subtypes

Fig. 2. Overview of exploratory graph analyses approaches.

rating criteria) and 128 nodes for natural landscapes (8 natural landscape image subtypes × 16 aesthetic rating criteria). Theoretically, results from Agnostic EGAs could fall along a spectrum of being driven by the aesthetic criteria, or the image subtype. If participant responses were based only aesthetic criteria (i.e., truly independent of the image subtype) we would find 16 different communities (e.g., one community for all beauty ratings, one community for all complexity ratings, etc.). On the other end of the spectrum – if responses were driven by image subtypes and not their aesthetic criteria – the network would contain only 8 communities, with each containing all ratings for a specific image subtype. For example, perhaps complexity is viewed similarly across all image subtypes. Or, people might respond similarly to beaches as a category distinct from their responses to forests, regardless of which aesthetic criteria is being considered.

3. Results

3.1. Aesthetic ratings agreement for exterior architecture and natural landscapes

Participants rated 16 randomly selected images (one image randomly drawn from each of the 8 natural landscapes subtypes, one image randomly drawn from each of the 8 exterior architecture subtypes) on the 16 criteria indicated in Table 1. To test the hypothesis that humans are more consistent in their aesthetic responses to natural environments than built environments, we performed a MM1 analysis of aesthetic ratings for each of the two overall image categories (i.e., exterior architecture and natural landscapes). Specifically, between-subject agreement in aesthetic ratings were calculated by iteratively correlating each individual participant's ratings with the mean ratings of all remaining participants, leading to a r value for each participant that indicated the extent to which they agreed with the remainder of the sample (z-transformed for inferential statistics to reduce bias, then transformed back to r for ease of interpretation). This procedure was performed twice – once for exterior architecture images and once for natural landscape images.

Consistent with our prediction and replicating Vessel et al. (2018), MM1 analysis of participant ratings across all aesthetic criteria and image subtypes indicated greater between-subject agreement in the aesthetic qualities of natural landscapes ($r = 0.42$) than exterior architecture ($r = 0.32$, $t = 9.03$, 95% CI = 0.09–0.15, $p < 0.001$). That is, people were more similar to each other in aesthetic preferences for natural landscapes than for the built environment.

3.2. EGA 1: overall psychological responses to exterior architecture and natural landscapes

We hypothesized that aesthetic responses to images of exterior architecture and natural landscapes would reduce to a few broad yet interconnected underlying psychological dimensions. We further predicted that these responses would correspond to fascination, coherence, and hominess. Because we were interested in comparing the underlying dimensions across the two overall image categories, EGAs were performed separately for exterior architecture and natural landscape images.

In line with prior work (Coburn et al., 2020), ratings across the different aesthetic criteria correlated strongly (exterior architecture: $\bar{r} = 0.43$; natural landscapes: $\bar{r} = 0.37$; Fig. S1). To mitigate potential redundancy, UVA was performed before conducting EGA. UVA results indicated redundancy between four criteria for exterior architecture images: exploration, interest, approach, and stimulation. UVA also revealed three separate clusters of redundant variables for natural landscapes – (1) order and modernity, (2) approach and exploration, and (3) interest, stimulation, and beauty. The latent variables of these redundant sets and remaining aesthetic criteria were used to form weighted, undirected networks (one for exterior architecture, one for natural landscapes), with nodes represented by the aesthetic rating criteria and edges constructed from the partial correlations between them. Item loadings – which are conceptually equivalent to PCA and factor loadings – are displayed in Table 2, with effect sizes interpreted as: small (0.15), moderate (0.25), and large (0.35; Christensen & Golino, 2021).

3.2.1. Exterior architecture

EGA identified three communities for images of exterior architecture at the overall image level (Fig. 3). Community 1 ($\lambda = 3.15$) was comprised of comfort, relaxation, hominess, personal, and natural, terms that reflect a sense of intimacy and comfort. We refer to this community as "Hominess", since it corresponded directly with the dimension of the same name recently identified for interior architectural spaces (Coburn et al., 2020). The second and third communities also mapped closely onto those previously found for interior architecture. Community 2 ("Coherence"; $\lambda = 1.38$) – which consisted of order, modernity, and complexity – reflects analytic judgements about the construction of the space, as opposed to emotional or affective responses to it. The fact that Coherence contained only analytic aesthetic criteria suggests this community may be comparatively less reliant on the emotion-valence system. Community 3 – "Fascination" ($\lambda = 3.68$) – included beauty, interest, and behavior-motivational aesthetic criteria (i.e., approach, explorability; suggesting sensory-motor influences) as well as emotional responses (i.e., valence, uplift, vitality, stimulation).

In examining the network for exterior architecture as a whole, the Coherence nodes appear comparatively isolated from the rest of the network (i.e., fewer – and weaker – edges). This pattern is also reflected in the network loadings (Table 2); criteria assigned to the Fascination and Hominess communities exhibited strong cross-loadings (i.e., they were related to multiple dimensions) but not to Coherence. To quantify these observations, we computed eigenvector centrality for each node in the network. Eigenvector centrality measures the relative position of nodes in a network by examining their connections to highly-connected nodes relative to their connections weakly-connected nodes (Bonacich, 2007). Results supported the observation that Coherence was isolated from the rest of the network; the relative position of Coherence nodes ($Mean_{EC} = 0.17$) was significantly lower than the relative position of all other network nodes ($Mean_{EC} = 0.76$ Wilcoxon rank sum exact test: 95% CI = 0.34–82.8, $p = 0.007$).

3.2.2. Natural landscapes

Three communities were also identified for natural landscapes. However, two aesthetic criteria – complexity and naturalness – exhibited low network loadings and were weakly connected to all other network nodes, *including the other nodes of their own community*. Eigenvector centrality of these two nodes (0.08) were significantly lower than those of all remaining nodes (0.68; Wilcoxon rank sum exact test: 95% CI = 0.15–0.95. $p = 0.03$). Together, this suggests that – at the overall image level – complexity and naturalness were qualitatively distinct from ratings for the remaining criteria and contributed minimally to their own community.

We thus performed a second EGA for natural landscapes after removing these two criteria. Results (Fig. 3) indicated the presence of just two communities. Note that we elected to retain both criteria for subsequent analyses (EGA 2: Agnostic EGA) for *a priori* theoretical reasons based on work emphasizing the importance of complexity and naturalness judgements to aesthetic experience of both architecture (Joye, 2007; Kaplan, 1995; Kaplan et al., 1972; Mehaffy & Salingaros, 2006; Taylor, 2021) and natural landscapes (Alexander, 2002; Berman et al., 2019).

Community 1 ("Hominess-Coherence": personal, hominess, comfort, and order-modern latent variable; $\lambda = 2.29$) once again related strongly to the previously-identified Hominess dimension. However, whereas Hominess was associated with naturalness for the built environment, it is closely linked with analytic judgements of order and modernity for

Table 2
EGA item loadings.

Exterior Architecture				Natural Landscapes		
Aesthetic Criteria	Hominess	Coherence	Fascination	Aesthetic Criteria	Hominess-Coherence	Fascination
Comfort	**0.23**		0.22	Comfort	**0.22**	0.31
Relaxation	**0.25**			Hominess	**0.21**	0.23
Natural	**0.16**			Personal	**0.25**	0.16
Hominess	**0.27**			OrdMod	**0.15**	0.09
Personal	**0.22**			Relaxation		**0.25**
Complexity	0.01	**0.03**	0.02	AprExp		**0.38**
Order	0.03	**0.12**	0.11	Valence		**0.33**
Modernity	0.02	**0.13**	0.07	Vitality		**0.23**
Vitality	0.19	0.1	**0.2**	Uplift		**0.28**
Uplift	0.17	0.15	**0.26**	IntStimBeauty		**0.33**
Valence	0.26		**0.28**			
ExpIntAprStim	0.2		**0.33**			
Beauty	0.19		**0.27**			
Eigenvalue	*3.15*	*1.38*	*3.68*	*Eigenvalue*	*2.29*	*4.14*

Note: Bold text indicates community in which aesthetic criteria was placed by EGA. Aesthetic criteria abbreviations indicated in Fig. 3 caption.

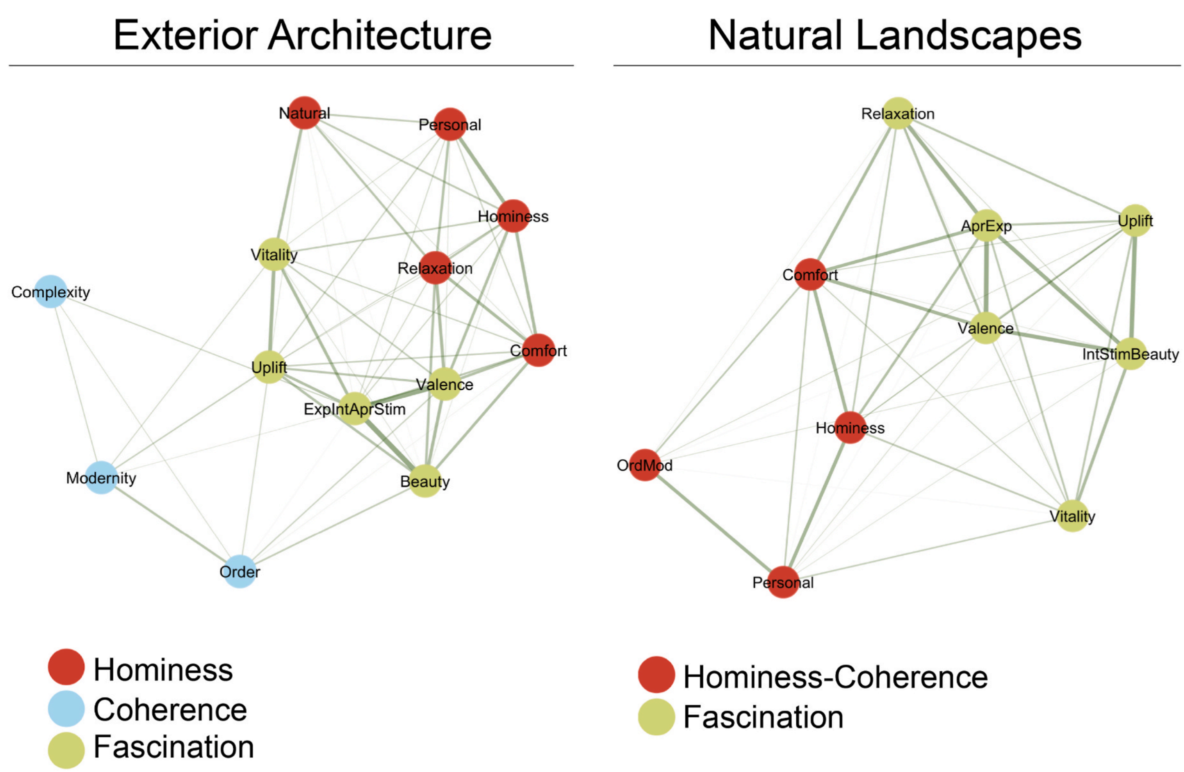

Fig. 3. Overall EGA results. Graphs formed from partial correlations between aesthetic rating criteria. Connectivity strength represented by edge thickness (thicker = stronger association). Natural landscape network formed after removal of complexity and natural.
Note: ExpIntAprStim = Latent variable from exploration, interest, approach, and stimulation; AprExp = latent variable from approach and exploration, IntStimBeauty = latent variable from interest, stimulation, and beauty; OrdMod = latent variable from order and modernity.

natural landscapes. Order and modernity – which comprised the Coherence dimension for built environments – may be more commonly used to describe characteristics of human artifacts. These results, therefore, indicate a dichotomy between natural and built environments. For the latter, spaces high in hominess look natural (i.e., *not* built by a person). By contrast, homey natural spaces appear ordered or modern (i.e., as if created by a human). This difference between built and natural spaces is consistent with theoretical perspectives indicating aesthetic preferences for human-made objects that appear natural, and preferences for naturally-occurring stimuli that appear ordered or constructed (Coburn et al., 2017, 2019; Dosen & Ostwald, 2016; Kant, 1790; Ulrich, 1993; Vartanian et al., 2013, 2015).

Community 2 ("Fascination"; λ = 4.14) contained ratings for valence, uplift, vitality, approach-exploration latent variable, interest-stimulation-beauty latent variable, and relaxation. With the exception of relaxation, these criteria are identical to the ones that comprised Fascination for exterior architecture images. As with exterior architecture images, this dimension captures behavior-motivational (i.e., approach, explorability) and emotional responses (i.e., valence, uplift, vitality, stimulation), suggesting a combined role of sensory-motor and emotion-valuation systems. The placement of relaxation within Fascination is broadly consistent with biophilic and stress-reduction frameworks that describe nature as a means to improve mood and affect (Berman et al., 2019; Joye, 2007; Kaplan & Kaplan, 1989; Ulrich, 1993).

3.3. EGA 2: agnostic approach

Having identified the underlying psychological responses for exterior architecture and natural landscapes overall, we next explored the extent to which participants' ratings were formed based on the image subtype (e.g., all beach images are clustered together, regardless of aesthetic rating), aesthetic rating (e.g., all complexity ratings are clustered together, regardless of image subtype), or some combination of both. A second round of EGA was performed in which each individual aesthetic rating for each image subtype was entered as a unique observation variable (Fig. 2B). That is, rather than grouping participant responses by aesthetic criteria (e.g., all complexity ratings placed in a single column), each individual rating was modeled as a unique node in the network (e.g., each complexity rating, for each image subtype, is its own observation variable).

Results are displayed in Fig. 4. EGA identified 10 communities for images of exterior architecture. Of note, one community contained all 8 complexity ratings, a second community contained all 8 naturalness ratings as well as 5 of the 8 ratings for modernity, and a third community contained 5 of the 8 ratings for order. This suggests that complexity, naturalness, modernity, and order criteria were rated similarly across the range of architectural styles. Complexity, naturalness, modernity, and order – as well as personalness – also emerged as unique communities for images of natural landscapes. Thus, for both built and natural environments, people's responses were similarly driven by these criteria across the different image subtypes. By contrast, other aesthetic rating criteria were not identified as dissociating responses in the agnostic EGA. Rather, variability on the remaining aesthetic criteria was more strongly influenced by the image subtype participants viewed than the criteria they considered.

To give a concrete example, consider ratings for two image subtypes – e.g., colonial buildings and pillared buildings – and three aesthetic criteria (e.g., complexity, beauty, and valence). Agnostic EGA results indicated that complexity ratings for colonial buildings and complexity ratings for pillared buildings were strongly associated (thus, both complexity ratings were placed in the same community). This association was stronger than the association for (1) colonial building complexity and colonial building beauty/valence, as well as (2) pillared building complexity and pillared building beauty/valence. That is, complexity ratings were distinct from ratings for beauty and valence (regardless of image subtype), and therefore placed in the same community. By contrast, the association between beauty and valence ratings for colonial buildings was greater than the association for (1) beauty ratings across image types, and (2) valence ratings across image types. The same trend was observed for pillared buildings. Thus, participant ratings for beauty and valence were strongly influenced by what image they were asked to consider (i.e., here, colonial or pillared buildings). In other words, complexity was rated similarly across image subtypes but the application of valence and beauty varied based on context (i.e., architectural styles/image subtypes).

4. Discussion

The present study tested the hypothesis that aesthetic experience for exterior architecture and natural landscapes reduce to a few psychological dimensions. We further assessed whether these experiences are shared across contexts (i.e., built vs. natural spaces; different natural settings and architectural styles) and individuals (between-subject agreement). Consistent with our hypothesis, aesthetic responses to exterior architecture reduced to three psychological constructs: Coherence, Fascination, and Hominess. For natural landscapes, we identified two dimensions: a combined Hominess-Coherence dimension and Fascination. Also in line with our hypothesis and replicating Vessel et al. (2018), people agreed in the aesthetic qualities of natural landscapes more consistently than they did for exterior architecture.

Our results extend recent work (Coburn et al., 2020) on environmental psychology beyond interior architecture spaces to the new contexts of building exteriors and natural landscapes. The three dimensions identified for exterior architecture – Fascination, Coherence, and Hominess – are a nearly-exact match of the three-dimensional structure for interior spaces. Crucially, Coburn et al. (2020) used images carefully constrained by architects across a number of visual features. No such curation efforts were taken in the present study. Thus, in addition to expanding past work to novel contexts (i.e., exterior architecture), we also used comparatively more natural stimuli (i.e., stimuli with more potentially-confounding variables) to more closely resemble responses in the real world (Snow & Culham, 2021). Thus, our findings suggest that Fascination, Coherence, and Hominess are broadly applicable aesthetic experiences to the built environment.

Responses to natural landscapes were also proximate to those identified for architecture spaces; EGA results again revealed Fascination, Coherence, and Hominess communities, although the latter two were less separable than in the case of built environments. This two-community framework is notable in light of Kaplan and Kaplan's influential preference matrix for outdoor landscapes, which argues that aesthetic experiences of the natural environment are rooted in two dimensions: understanding and exploration (Kaplan et al., 1972). Understanding refers to the human desire to make sense of "what is going on", and is related how a space's features can be viewed, recognized, or remembered (i.e., Coherence). The second dimension of the preference

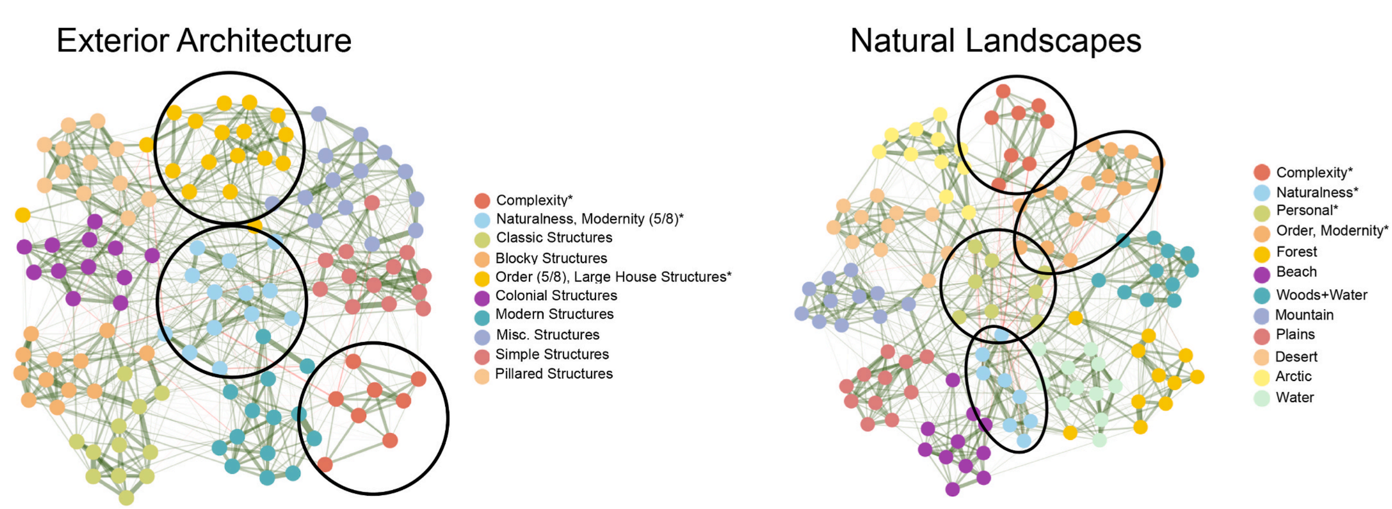

Fig. 4. Agnostic EGA results. Communities formed from aesthetic criteria (as opposed to image subtype) are circled and indicated by *.

matrix – exploration – is conceptually similar to Fascination, which included behavior-motivation responses. Coherence and Fascination were dissociable dimensions in the present study, consistent with this conceptual framework. Our findings suggest, however, that this framework should be expanded to also consider Hominess.

Hominess – the degree to which a space makes inhabitants feel cozy or “at home” (Wiking & Wiking, 2017) – is understudied in empirical aesthetics. The present study shows that hominess generalizes beyond highly curated images of interior spaces (Coburn et al., 2020) to external built and natural spaces. The identification of Hominess in exterior architecture and natural landscapes raises the possibility that this is a widely experienced psychological response for both natural and human-made environments. Further, Agnostic EGA for natural landscapes identified “personalness” – one of the criteria in Hominess – as a distinct community. That is, participant responses when asked to consider this criterion were comparatively independent of image-specific characteristics that may have biased responses to many of the other aesthetic criteria.

Intriguingly, the amount of order in a space may differentially induce feelings of hominess for natural and human-made contexts. In the case of natural landscapes, greater order (and modernity) was positively associated with feelings of hominess. For human-made spaces, however, more homey spaces appeared natural, and were weakly related to order. This distinction fits with accounts that suggest humans prefer natural objects that look human-made (i.e., here, order or modern), and human-made objects that look natural (Coburn et al., 2017, 2019; Dosen & Ostwald, 2016; Kant, 1790; Ulrich, 1993; Vartanian et al., 2013, 2015). Nature is frequently valued for its purported relaxing or comforting effects (e.g., Berman et al., 2019, 2008; Chang et al., 2020; Kaplan, 1995; Ulrich, 1993), leading to a long-standing effort to incorporate nature into the built environment (e.g., Abboushi et al., 2019; Joye, 2007; Taylor, 2021; Ulrich, 1993). Critically, however, it would be inaccurate to describe *all* natural environments as relaxing. For example, a person placed in the middle of an ocean or deep in a jungle is unlikely to be soothed or comforted. Rather, to be comforting, it helps for the natural environment to be partially controlled or ordered – a clean, calm beach or manicured camp ground contain a level of organization that makes these otherwise dangerous or scary environments hospitable. This apparent necessity of order is reflected in numerous evolutionary-based accounts of natural preference that emphasize safety or openness (e.g., Dosen & Ostwald, 2016; Joye, 2007; Joye & De Block, 2011; Ulrich, 1993). The observed relationship between order and Hominess for natural landscapes accords with these perspectives.

Our findings are broadly consistent with the aesthetic triad framework, which presents aesthetic experience as an emergent psychological state rooted in interactions between the sensory-motor, emotion-valuation, and knowledge-meaning systems (Chatterjee & Vartanian, 2014, 2016). The underlying psychological responses identified in the current study were likely supported by all three systems. However, the emotion-valuation system may have been comparatively less involved in Coherence, which was comprised of analytic ratings about a space’s appearance or construction, as opposed to self-reflective judgements about one’s inner state. This qualitative distinction is supported by other models of aesthetic experience (Chatterjee, 2014; Leder et al., 2004) that differentiate between analytic judgments (i.e., evaluations of an object; here, Coherence) and emotions (which underscore Fascination and Hominess; Chatterjee, 2003).

Quantitatively, network models further indicated that the neurocognitive mechanisms supporting Coherence may be distinct from those underlying Fascination and Hominess. For exterior architecture images, Coherence was less integrated into the remainder of the aesthetic network at the overall level. For natural landscapes, although Coherence and Hominess were more closely associated, the analytic aesthetic judgements – complexity, order, modernity, and natural – were nonetheless isolated from the rest of the network. By contrast, Fascination and Hominess were strongly connected. One reason for lower integration of Coherence with the other two dimensions in the network might be due to its different weightings in the aesthetic triad framework.

Agnostic EGA results further indicate that analytic judgements may generalize across contexts. For exterior architecture, all three aesthetic criteria belonging to Coherence were partially distinguishable from the images themselves. That is, these criteria were applied similarly across the different architectural styles, but all of the remaining aesthetic criteria (with the exception of naturalness, another analytic judgement; Coburn et al., 2020; Imamoglu, 2000) varied as a function of the image subtype. The same aesthetic criteria were also disentangled from stimulus subtype for natural landscapes. The fact that these trends were observed for both architecture *and* natural landscapes is consistent with accounts indicating that perceptions of order and complexity are independent of other features of the environment (Alexander, 2002; Kaplan & Kaplan, 1989; Mehaffy & Salingaros, 2006). Indeed, analytic appraisals about the amount and arrangement of patterns influence human responses across a wide range of visual stimuli (Dio et al., 2007; Dosen & Ostwald, 2016; Kaplan et al., 1972; Palmer et al., 2013; Reber et al., 2004). Our results support these perspectives by demonstrating that analytic judgements operate somewhat independently of stimulus-specific qualities across architectural and natural settings. Future inquiries into the domain-independence of analytic judgements should ask participants to make analytic (e.g., order, complexity) and non-analytic (e.g., valence, comfort) aesthetic judgements on an even wider range of visual stimuli (e.g., paintings and sculptures of varying styles, buildings, dance). Based on the present findings, we predict that analytic judgements would be more associated across visual domains than non-analytic judgements.

Our findings also indicate variability in psychological responses across contexts, particularly for responses involving the emotion-valuation system. First, overall EGAs revealed different community organization for built and natural environments. That is, although some responses were shared across both kinds of images (i.e., Fascination), there were also differences in aesthetic criteria community assignment. Critically, however, differences in community organization were also observed *within* overall image categories. The Agnostic EGAs demonstrated that ratings for many of the aesthetic criteria *were* strongly influenced by image subtype (i.e., architectural style; natural setting). This finding is in line with prior work demonstrating that the relationship between specific features of a built environment and the psychological responses they induce may not be shared across contexts (Graham et al., 2015).

Results also provided clear evidence that aesthetic experience varies across individuals, putatively because of top-down differences from the knowledge-meaning system. However, between-subject variability was not the same for natural and human-made environments. As expected, people agree more often in the aesthetic criteria of natural landscapes than they do to exterior architectural spaces. Along with prior work reporting similar results from the same image set (Vessel et al., 2018), our findings indicate greater shared taste for naturally-occurring stimuli than for artifacts of human culture. One interpretation of this result is that evolutionarily-evolved preferences may render natural environments more universally relevant (Berman et al., 2008; Chatterjee, 2014; Nadal & Chatterjee, 2019; Ulrich, 1993). By contrast, preferences for built environments may be more experience-dependent or subject to individual and cultural aesthetic sensibilities.

The results of the present study have practical implications. One of the motivating factors of environmental and architectural psychology is to assess the unique ways in which the surrounding environment can influence psychological functioning and wellness (Berman et al., 2019). An ambitious goal of this line of work is to generate predictive models of how and why certain environmental features affect individuals (Coburn et al., 2017). The underlying responses identified here and in prior work (Coburn et al., 2020) can be conceptualized as “targets” – psychological states that are evoked by the surrounding environment. Designers or architects, therefore, may be able to examine how certain features or spaces modulate these states, either before or after construction. Importantly, however, the present study clearly advocates against the notion that findings gleamed from one kind of space will necessarily translate to another. Thus, it would be critical to carefully consider stimulus-specific differences, especially in real-world settings.

In sum, we identified three underlying psychological constructs for exterior architecture spaces: Coherence, Fascination, and Hominess. Natural landscapes were best characterized by just two: a combined Hominess-Coherence dimension and Fascination. Aesthetic experience was subject to variability across participants for architectural exteriors, but was more shared for natural landscapes. Thus, our results point to a mixture of context-independent and context-specific responses across different kinds of environments. Regarding the former, analytic judgements (i.e., Coherence) operated somewhat independently across context. That is, participant ratings for the analytic criteria were less bound to the specific stimuli and the corresponding emotional responses. The remaining criteria varied across the different kinds of images, demonstrating that the extent to which they manifest in separable psychological responses is, at least partially, context specific. Future inquiries could investigate whether psychological responses identified in the present study are also experienced in the real-world.

Author contributions

Adam B. Weinberger: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, visualization. Alexander P. Christensen: Formal analysis, Writing – review & editing. Alexander Coburn: Conceptualization, Writing – review & editing. Anjan Chatterjee: Conceptualization, Writing – review & editing, supervision, funding acquisition.

Author note and data availability

The authors declare no competing interests. Data, code, and preregistration supporting the manuscript are publicly available on the Open Science Framework at: https://osf.io/a3k7x/.

Acknowledgments

The authors thank Farhan Jivraj for his help selecting and classifying images. They also thank Edward Vessel for sharing stimuli for use in the present study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2021.101676.

Funding

This research was funded by the ALPAS Gift Fund.

References

Abboushi, B., Elzeyadi, I., Taylor, R., & Sereno, M. (2019). Fractals in architecture: The visual interest, preference, and mood response to projected fractal light patterns in interior spaces. *Journal of Environmental Psychology, 61*, 57–70. https://doi.org/10.1016/j.jenvp.2018.12.005

Alexander, C. (1977). *A pattern language: Towns, buildings, construction*. Oxford university press.

Alexander, C. (2002). *The nature of order: The phenomenon of life*. Taylor & Francis.

Bachelard, G. (2014). *The poetics of space*. Penguin Classics.

Barrett, L. F., Mesquita, B., Ochsner, K. N., & Gross, J. J. (2007). The experience of emotion. *Annual Review of Psychology, 58*(1), 373–403. https://doi.org/10.1146/annurev.psych.58.110405.085709

Berlyne, D. E. (1963). Complexity and incongruity variables as determinants of exploratory choice and evaluative ratings. *Canadian Journal of Psychology/Revue Canadienne de Psychologie, 17*(3), 274.

Berlyne, D. E. (1970). Novelty, complexity, and hedonic value. *Perception & Psychophysics, 8*(5), 279–286.

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science, 19*(12), 1207–1212. https://doi.org/10.1111/j.1467-9280.2008.02225.x

Berman, M. G., Stier, A. J., & Akcelik, G. N. (2019). Environmental neuroscience. *American Psychologist, 74*(9), 1039.

Böhme, G. (1993). Atmosphere as the fundamental concept of a new aesthetics. *Thesis Eleven, 36*(1), 113–126.

Bonacich, P. (2007). Some unique properties of eigenvector centrality. *Social Networks, 29*(4), 555–564. https://doi.org/10.1016/j.socnet.2007.04.002

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health, 10*(1), 456. https://doi.org/10.1186/1471-2458-10-456

Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., Vries, S. de, Flanders, J., Folke, C., Frumkin, H., Gross, J. J., Hartig, T., Kahn, P. H., Kuo, M., Lawler, J. J., Levin, P. S., Lindahl, T., Meyer-Lindenberg, A., Mitchell, R., Ouyang, Z., Roe, J., … Daily, G. C. (2019). Nature and mental health: An ecosystem service perspective. *Science Advances, 5*(7), Article eaax0903. https://doi.org/10.1126/sciadv.aax0903

Brown, S., Gao, X., Tisdelle, L., Eickhoff, S. B., & Liotti, M. (2011). Naturalizing aesthetics: Brain areas for aesthetic appraisal across sensory modalities. *NeuroImage, 58*(1), 250–258. https://doi.org/10.1016/j.neuroimage.2011.06.012

Bullot, N. J., & Reber, R. (2013). *A psycho-historical research program for the integrative science of art*.

Chang, C., Cheng, G. J. Y., Nghiem, T. P. L., Song, X. P., Oh, R. R. Y., Richards, D. R., & Carrasco, L. R. (2020). Social media, nature, and life satisfaction: Global evidence of the biophilia hypothesis. *Scientific Reports, 10*(1), 4125. https://doi.org/10.1038/s41598-020-60902-w

Chatterjee, A. (2003). *Prospects for a cognitive neuroscience of visual aesthetics*.

Chatterjee, A. (2014). *The aesthetic brain: How we evolved to desire beauty and enjoy art*. Oxford University Press.

Chatterjee, A., & Vartanian, O. (2014). Neuroaesthetics. *Trends in Cognitive Sciences, 18*(7), 370–375. https://doi.org/10.1016/j.tics.2014.03.003

Chatterjee, A., & Vartanian, O. (2016). Neuroscience of aesthetics. *Annals of the New York Academy of Sciences, 1369*(1), 172–194.

Christensen, A. P., Garrido, L. E., & Golino, H. (2020). *Unique variable analysis: A novel approach for detecting redundant variables in multivariate data*.

Christensen, A. P., & Golino, H. (2021). On the equivalency of factor and network loadings. *Behavior Research Methods*. https://doi.org/10.3758/s13428-020-01500-6

Coburn, A., Kardan, O., Kotabe, H., Steinberg, J., Hout, M. C., Robbins, A., MacDonald, J., Hayn-Leichsenring, G., & Berman, M. G. (2019). Psychological responses to natural patterns in architecture. *Journal of Environmental Psychology, 62*, 133–145. https://doi.org/10.1016/j.jenvp.2019.02.007

Coburn, A., Vartanian, O., & Chatterjee, A. (2017). Buildings, beauty, and the brain: A neuroscience of architectural experience. *Journal of Cognitive Neuroscience, 29*(9), 1521–1531. https://doi.org/10.1162/jocn_a_01146

Coburn, A., Vartanian, O., Kenett, Y. N., Nadal, M., Hartung, F., Hayn-Leichsenring, G., Navarrete, G., González-Mora, J. L., & Chatterjee, A. (2020). Psychological and neural responses to architectural interiors. *Cortex, 126*, 217–241. https://doi.org/10.1016/j.cortex.2020.01.009

Day, H. Y. (1967). Evaluations of subjective complexity, pleasingness and interestingness for a series of random polygons varying in complexity. *Perception & Psychophysics, 2*(7), 281–286.

Dio, C. D., Macaluso, E., & Rizzolatti, G. (2007). The golden beauty: Brain response to classical and renaissance sculptures. *PloS One, 2*(11), Article e1201. https://doi.org/10.1371/journal.pone.0001201

Dosen, A. S., & Ostwald, M. J. (2016). Evidence for prospect-refuge theory: A meta-analysis of the findings of environmental preference research. *City, Territory and Architecture, 3*(1), 4. https://doi.org/10.1186/s40410-016-0033-1

Dutton, R. (2014). The built housing environment, wellbeing, and older people. *Wellbeing: A Complete Reference Guide, 1–38*.

Earthman, G. I. (2004). *Prioritization of 31 criteria for school building adequacy*.

Ellard, C. (2015). *Places of the heart: The psychogeography of everyday life*. Bellevue literary press.

Evans, G. W. (2003). The built environment and mental health. *Journal of Urban Health, 80*(4), 536–555. https://doi.org/10.1093/jurban/jtg063

Freedberg, D., & Gallese, V. (2007). Motion, emotion and empathy in esthetic experience. *Trends in Cognitive Sciences, 11*(5), 197–203. https://doi.org/10.1016/j.tics.2007.02.003

Gallese, V., & Freedberg, D. (2007). Mirror and canonical neurons are crucial elements in esthetic response. *Trends in Cognitive Sciences, 11*(10), 411.

Golino, H. F., & Epskamp, S. (2017). Exploratory graph analysis: A new approach for estimating the number of dimensions in psychological research. *PloS One, 12*(6), Article e0174035. https://doi.org/10.1371/journal.pone.0174035

Golino, H, F, & Christensen, A, P (2021). Exploratory graph analysis - a framework for estimating the number of dimensions in multivariate data using network psychometrics. *R package version 0.9.9*.

Golino, H., Shi, D., Christensen, A. P., Garrido, L. E., Nieto, M. D., Sadana, R., Thiyagarajan, J. A., & Martinez-Molina, A. (2020). Investigating the performance of exploratory graph analysis and traditional techniques to identify the number of latent factors: A simulation and tutorial. *Psychological Methods*.

Graham, L. T., Gosling, S. D., & Travis, C. K. (2015). The psychology of home environments: A call for research on residential space. *Perspectives on Psychological Science, 10*(3), 346–356.

Hayn-Leichsenring, G. U., Kenett, Y. N., Schulz, K., & Chatterjee, A. (2020). Abstract art paintings, global image properties, and verbal descriptions: An empirical and computational investigation. *Acta Psychologica, 202*, 102936. https://doi.org/10.1016/j.actpsy.2019.102936

Humphries, S., Rick, J., Weintraub, D., & Chatterjee, A. (2021). Movement in aesthetic experiences: What we can learn from Parkinson's disease. *Journal of Cognitive Neuroscience*, 1–14.

Imamoglu, Ç. (2000). Complexity, liking and familiarity: Architecture and non-architecture Turkish students' assessments of traditional and modern house facades. *Journal of Environmental Psychology, 20*(1), 5–16.

James, W. (1985). In *Psychology: The briefer course (1892)*. U of Notre Dame P. Gordon Allport. Notre Dame.

Joye, Y. (2007). Architectural lessons from environmental psychology: The case of biophilic architecture. *Review of General Psychology*, 305–328.

Joye, Y., & De Block, A. (2011). "Nature and I are two": A critical examination of the biophilia hypothesis. *Environmental Values, 20*(2), 189–215.

Kant, I. (1790). *Critique of judgment*. Hackett Publishing.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology, 15*(3), 169–182.

Kaplan, R., & Kaplan, S. (1989). *A psychological perspective* (Vol. 6).

Kaplan, S., Kaplan, R., & Wendt, J. S. (1972). Rated preference and complexity for natural and urban visual material. *Perception & Psychophysics, 12*(4), 354–356.

Killeen, P. R. (2001). The four causes of behavior. *Current Directions in Psychological Science, 10*(4), 136–140.

Kirk, U., Skov, M., Christensen, M. S., & Nygaard, N. (2009). Brain correlates of aesthetic expertise: A parametric fMRI study. *Brain and Cognition, 69*(2), 306–315. https://doi.org/10.1016/j.bandc.2008.08.004

Leder, H. (2013). Next steps in neuroaesthetics: Which processes and processing stages to study? *Psychology of Aesthetics, Creativity, and the Arts, 7*(1), 27.

Leder, H., Belke, B., Oeberst, A., & Augustin, D. (2004). A model of aesthetic appreciation and aesthetic judgments. *British Journal of Psychology, 95*(4), 489–508. https://doi.org/10.1348/0007126042369811

MacKerron, G., & Mourato, S. (2013). Happiness is greater in natural environments. *Global Environmental Change, 23*(5), 992–1000. https://doi.org/10.1016/j.gloenvcha.2013.03.010

Martindale, C. (1990). *The clockwork muse: The predictability of artistic change*. Basic Books.

Mehaffy, M. W., & Salingaros, N. A. (2006). *Geometrical fundamentalism* (Vol. 25).

Mehta, R., & Zhu, R. J. (2009). Blue or red? Exploring the effect of color on cognitive task performances. *Science, 323*(5918), 1226–1229.

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences, 7*(3), 134–140. https://doi.org/10.1016/S1364-6613(03)00028-7

Mundfrom, D. J., Shaw, D. G., & Tian Lu, K. (2005). Minimum sample size recommendations for conducting factor Analyses. *International Journal of Testing, 5*(2), 159–168. https://doi.org/10.1207/s15327574ijt0502_4

Nadal, M., & Chatterjee, A. (2019). Neuroaesthetics and art's diversity and universality. *Wiley Interdisciplinary Reviews: Cognitive Science, 10*(3), e1487. https://doi.org/10.1002/wcs.1487

Newman, G. E., & Bloom, P. (2012). Art and authenticity: The importance of originals in judgments of value. *Journal of Experimental Psychology: General, 141*(3), 558.

Nowick, K., Gernat, T., Almaas, E., & Stubbs, L. (2009). Differences in human and chimpanzee gene expression patterns define an evolving network of transcription factors in brain. *Proceedings of the National Academy of Sciences, 106*(52), 22358–22363. https://doi.org/10.1073/pnas.0911376106

Oostendorp, A., & Berlyne, D. E. (1978). Dimensions in the perception of architecture:I. Identification and interpretation of dimensions of similarity. *Scandinavian Journal of Psychology, 19*(1), 73–82. https://doi.org/10.1111/j.1467-9450.1978.tb00305.x

Palmer, S. E., Schloss, K. B., & Sammartino, J. (2013). Visual aesthetics and human preference. *Annual Review of Psychology, 64*(1), 77–107. https://doi.org/10.1146/annurev-psych-120710-100504

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience? *Personality and Social Psychology Review, 8*(4), 364–382.

Silvia, P. J. (2005). Cognitive appraisals and interest in visual art: Exploring an appraisal theory of aesthetic emotions. *Empirical Studies of the Arts, 23*(2), 119–133.

Silvia, P. J. (2008). Interest—the curious emotion. *Current Directions in Psychological Science, 17*(1), 57–60.

Snow, J. C., & Culham, J. C. (2021). The treachery of images: How realism influences brain and behavior. *Trends in Cognitive Sciences*. https://doi.org/10.1016/j.tics.2021.02.008. S1364661321000528.

Specker, E., Fried, E. I., Rosenberg, R., & Leder, H. (2021). Associating with art: A network model of aesthetic effects. *Collabra: Psychology, 7*(1), 24085. https://doi.org/10.1525/collabra.24085

Taylor, R. (2021). The potential of biophilic fractal designs to promote health and performance: A review of experiments and applications. *Sustainability, 13*(2), 823. https://doi.org/10.3390/su13020823

Thakral, P. P., Moo, L. R., & Slotnick, S. D. (2012). A neural mechanism for aesthetic experience. *NeuroReport, 23*(5), 310–313. https://doi.org/10.1097/WNR.0b013e328351759f

Ulrich, R. S. (1991). Effects of interior design on wellness: Theory and recent scientific research. *Journal of Health Care Interior Design, 3*(1), 97–109.

Ulrich, R. S. (1993). Biophilia, biophobia, and natural landscapes. *The Biophilia Hypothesis, 7*, 73–137.

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Gonzalez-Mora, J. L., Leder, H., Modroño, C., Nadal, M., Rostrup, N., & Skov, M. (2015). Architectural design and the brain: Effects of ceiling height and perceived enclosure on beauty judgments and approach-avoidance decisions. *Journal of Environmental Psychology, 41*, 10–18. https://doi.org/10.1016/j.jenvp.2014.11.006

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Leder, H., Modroño, C., Nadal, M., Rostrup, N., & Skov, M. (2013). Impact of contour on aesthetic judgments and approach-avoidance decisions in architecture. *Proceedings of the National Academy of Sciences, 110*(Supplement 2), 10446–10453.

Vartanian, O., & Skov, M. (2014). Neural correlates of viewing paintings: Evidence from a quantitative meta-analysis of functional magnetic resonance imaging data. *Brain and Cognition, 87*, 52–56. https://doi.org/10.1016/j.bandc.2014.03.004

Vessel, E. A., Maurer, N., Denker, A. H., & Starr, G. G. (2018). Stronger shared taste for natural aesthetic domains than for artifacts of human culture. *Cognition, 179*, 121–131. https://doi.org/10.1016/j.cognition.2018.06.009

Wiking, M., & Wiking, M. (2017). *The little book of hygge: Danish secrets to happy living*. HarperCollins.