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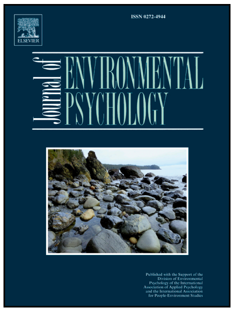

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Individual Differences in Preference for Architectural Interiors

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Abstract

Preference for architectural interiors can be explained using three psychological dimensions: *Coherence* (ease for organizing and comprehending a scene), *Fascination* (a scene's informational richness and generated interest), and *Hominess* (how much a space feels personal). We tested the hypothesis that their contributions to preference might vary based on individual differences by analyzing data from design students, participants with autism spectrum disorder, and neurotypical controls who rated images of interiors on liking and approach-avoidance decisions. For design students, only Coherence drove choices, whereas in participants with autism spectrum disorder and neurotypical controls Hominess and Fascination also contributed, respectively. Coherence is paramount for design students because it references the structural organization of spaces, and is informed by formal training. For autism spectrum disorder, Hominess matters because preference for familiarity, physical proximity, and difficulty in mental simulation are relevant to that population, whereas interest in visual exploration can explain Fascination's role in neurotypical controls.

Keywords: Architecture, design, expertise, autism spectrum disorder, proxemics.

1.1 Introduction

Urban dwellers worldwide spend approximately 90% of their time indoors (Klepeis et al., 2001; Ott, 1989). In addition, there is now increasing recognition that the physical and visual features of the built environment can impact our mood, thinking, and wellbeing (Adams, 2014; Cooper & Burton, 2014; Ellard, 2015; Hartig, 2008; Joye, 2007). For example, incorporating natural features such as greenery into the built environment can improve mood (Bowler et al., 2010), and accelerate recovery from stress and surgery (Ulrich, 1984; Ulrich et al., 1991). Physical and visual features of the built environment can also impact the functioning associated with pathological states. For example, patients with Alzheimer's disease are more likely to get lost if they navigate in interiors with monotonous architectural composition, and less likely to do so if their design incorporates frequent visual reference points and exterior views (Passini et al., 2000). It is therefore perhaps not surprising that when presented with images of room interiors, beauty judgments are the strongest determinant our willingness to live in those spaces (Ritterfeld & Cupchik, 1996).

Recently, and in part triggered by burgeoning research in the nascent domain of the neuroscience of architecture (Coburn et al., 2017), there has been strong interest in understanding the role of basic design features in preference for architecture. Generally, this work has involved isolating specific design features in architecture, and studying how they impact viewers. For example, extending the literature that people prefer curved over angular designs (for review see Goméz-Puerto et al., 2015), there is now evidence to show that people prefer curvilinear rather than rectilinear airport passenger areas (van Oel & van den Berkhof, 2013), architectural facades (Ruta et al., 2019), and interior spaces (Dazkir & Read, 2012). In turn, Vartanian et al. (2013) used functional magnetic resonance imaging (fMRI) to examine the neural correlates of preference for contour in architectural design by presenting participants with images of interior rooms that were either curvilinear or rectilinear under two different conditions: In the beauty judgment condition participants were instructed to rate the spaces as either 'beautiful' or 'not beautiful', whereas in the approach-avoidance conditions they were instructed to decide whether they would opt to enter or exit the space ('enter' vs. 'exit'). In the beauty judgment condition participants were more likely to find curvilinear interiors beautiful, and viewing curvilinear interiors activated the anterior cingulate cortex—a structure in the brain's core emotion network that is responsive to the reward properties and emotional valence of objects (Barrett et al., 2007; Barrett & Wager, 2006). This observation, in addition with the finding that ratings of pleasantness collected outside of the fMRI scanner accounted for nearly 60% of the variance in beauty ratings—reinforced the historically old idea that the perceived beauty of curves might owe to the feelings they evoke, such that "curves are in general *felt* to be more beautiful than straight lines" (Gordon, 1909, p. 169). In contrast, contour had no effect on approach-avoidance decisions, although viewing curvilinear spaces in that condition was correlated with greater activation in the visual cortex, suggesting that the brain is sensitive to this design feature. In a complementary study, Banaei and colleagues (2017) investigated brain activity during 3D perception of architectural spaces using a portable electroencephalogram (EEG) device while participants walked through different interior forms varying in contour in virtual reality (VR). Their results demonstrated that rooms with curvilinear contour engaged the anterior cingulate cortex. Given that this region was engaged using both fMRI and EEG in the context of varying experimental designs, this offers convergent evidence regarding its sensitivity to contour in architectural design.

Aside from contour, researchers have also studied the impact of other architectural design features on perceivers' psychological responses, including perceived enclosure and ceiling height (Vartanian et al., 2015). Regarding the former, perceived enclosure can be defined as the perceived degree of movement (i.e., permeability)—both visual and locomotive—through space (see Stamps, 2005, 2010; Stamps & Krishnan, 2004). Drawing on evolutionary arguments, Stamps (2005, 2010) has proposed that permeability has a direct bearing on survival by enabling the organism to see, hide, and identify threats. As such, it continues to impact our psychological and physiological responses in interior spaces to this day. In a particularly poignant demonstration of this relationship, Fich et al. (2014) used a virtual version of the Trier Social Stress Test, in which the space was computer generated and properties of the associated space could be systematically manipulated—specifically perceived enclosure. The authors were able to demonstrate that there was significantly greater secretion of cortisol—a reliable biomarker of stress—when a person gave an interview in an enclosed than an open space. Using fMRI, Vartanian et al. (2015) demonstrated that participants were more likely to find open than enclosed spaces beautiful, and also more likely to opt to enter them. Interestingly, in the approach-avoidance condition, enclosed spaces activated the anterior midcingulate cortex region of the cingulate gyrus, which has strong connections to the amygdala—a region of the brain sensitive to the perception and detection of threats. These findings are consistent with the idea that enclosed spaces can generate a sense of stress and threat in viewers. Regarding ceiling height, it has similarly been shown that people prefer rooms with higher than lower ceilings, and that viewing higher ceilings is correlated with activation in the brain's dorsal visual stream (i.e., precuneus and middle frontal gyrus), consistent with the idea people might prefer high ceilings because they enable visuospatial exploration more so than do rooms with lower ceilings.

1.1.1 Individual differences

Recently, researchers have turned their attention to exploring individual differences in sensitivity to the design features discussed above. This approach is motivated by findings indicating that people differ markedly in their preference for visual features such as complexity, symmetry, contour, and balance, and that such variation must be taken into consideration when modelling preferences (Corradi et al., 2020). Focusing on formal training, Vartanian et al. (2019) examined the impact of expertise in architecture and design on preference for curvature. Specifically, they set out to test two competing hypotheses. On the one hand, earlier studies had shown that in comparison to novices, experts in the visual arts are affected less by visual features and more by compositional and historical features of artworks (e.g., Cleeremans et al., 2016; Locher, 1996; Lundy, 2010; Parsons, 1987; Silvia, 2013). This line of evidence would suggest that contour—being a relatively visual feature—might have less of an impact on design experts than had been observed in participants with no formal training in architecture and design. On the other hand, Cotter and colleagues (2017) investigated the effects of artistic expertise (Smith & Smith, 2006) and openness to experience (using multiple measures including NEO-FFI, Costa & McCrae, 1992) on preference, and found that individuals higher in artistic expertise or openness to experience showed greater preference for curvature for abstract unfamiliar shapes consisting of randomly generated polygons. Furthermore, although they also preferred circles over hexagons drawn from the Preference for Balance Test (Wilson & Chatterjee, 2005), this effect was not moderated by individual differences. Their finding suggested that domain-general traits (e.g., openness to experience) frequently associated with creativity and observed in architects (see MacKinnon, 1962) might in fact be associated with increased preference for curvilinear interior design. To test these two competing predictions, Vartanian and colleagues (2019) presented a sample of working architects and designers and control participants recruited from a university with a subset of the images from Vartanian et al. (2013), instructing them to complete the same two tasks. The results demonstrated that when the task involved beauty judgments, architects exhibited greater preference for curvilinear than rectilinear design. In contrast, when the task involved approach-avoidance decisions, control participants exhibited greater preference for curvilinear than rectilinear design. These results demonstrated that the impact of expertise on preference in the domain of architecture varies as a function of context, which can in turn engage and trigger differing processes that contribute to the computation of preference.

In turn, Palumbo and colleagues (2020) extended the study of preference for curvature in architecture to two theoretically-relevant groups, namely persons with autism spectrum disorder and design quasi-experts. Regarding the former, Belin and colleagues (2017) had found that unlike participants with neurotypical development, persons with autism spectrum disorder reported positive feelings with jagged-edged stimuli. They explained this effect by referring to the atypical experience of visual information and emotions in persons with autism spectrum disorder. Combined with the finding that curved objects and words are associated with positive valence whereas angular objects and words are associated with negative valence (Bar & Neta, 2007; Dazkir & Read, 2012; Palumbo et al., 2015; Vartanian et al., 2013), they hypothesized that this preference would be attenuated in persons with autism spectrum disorder because of known abnormalities in both sensory (visuospatial) and affective processing in that population. In addition, regarding expertise in architecture and design, Vartanian et al. (2019) had demonstrated that experts in architecture and design exhibit a different preference profile for curvature depending on the task. To determine whether the same effect could be extended to *quasi-experts*—defined as people with some but not expert-level background and training in the domain (Kozbelt & Kaufman, 2014; Silvia, 2006)—Palumbo and colleagues (2020) also collected data from university-level students of industrial design. In Experiment 1 they administered the same two tasks as Vartanian et al. (2013) using a subset of the original stimuli to a neurotypical sample (i.e., control) and persons with autism spectrum disorder. They found that compared to neurotypical controls, persons with autism spectrum disorder were significantly less prone to like curvilinear spaces. No difference was found in the approach-avoidance condition. The results of Experiment 2 in which the same task was administered to university-level students specializing in industrial design demonstrated that they were significantly more prone to dislike curvilinear spaces, and significantly more likely to opt to exit than enter them. First and foremost, these results indicated that persons with autism spectrum disorder do not exhibit the same preference for curvilinear design as was the case for persons with neurotypical development. In part, this outcome might have been driven by familiarity, in that the rectilinear interiors could have been perceived as more similar to their own living and working spaces. In addition, they demonstrated that the impact of expertise and formal training on preference can be subtle, even exhibiting differences between true experts and quasi-experts, as has been observed elsewhere with other tasks and stimuli (Kaufman et al., 2013).

1.1.2 Three dimensions of preference in architecture

Motivated by the idea that people's preferences for architectural interiors could be explained by a limited number of psychological dimensions, Coburn et al. (2020) conducted a series of experiments to lay the groundwork for a psychology of architecture. In Experiment 1 they administered the stimuli from Vartanian et al. (2013) to a large sample of participants who were asked to rate them on a subset of 16 scales (e.g., complexity, beauty, naturalness, etc.). In turn, those ratings were subjected to psychometric network analysis (PNA) and principal components analysis (PCA) to identify whether or not the original 16 measures could be reduced to a few latent psychological dimensions. Both PNA and PCA converged to demonstrate that people's responses to architectural interiors can be explained using three psychological dimensions: *Coherence* (ease with which one organizes and comprehends a scene), *Fascination* (a scene's informational richness and generated interest), and *Hominess* (extent to which a scene feels like a personal space). The researchers also investigated correlations between those ratings and two Global Image Properties (GIPs) of architectural scenes—specifically self-similarity and complexity. Those GIPs were chosen because in earlier work both had been found to correlate highly with preference ratings in studies of visual art, architecture and landscapes. The results demonstrated that the observed effects were not driven by those two visual properties of the stimuli. Next, in Experiment 2, Coburn et al. (2020) tested the robustness of their findings by asking a new set of participants to rate a subset of the architectural images on all 9 rating scales which had been found to be non-redundant in

Experiment 1. This new design enabled them to perform a more robust PCA that accounted for each person's within-participant ratings for each architectural condition across all of the dependent measures of interest. The researchers found that the same three dimensions accounted for people's preference for architectural interiors, reinforcing the robustness of the three-dimensional model. Importantly, the results from Experiments 1-2 enabled the researchers to calculate PCA-derived scores for Coherence, Fascination, and Hominess for each of the 200 stimuli from Vartanian et al. (2013). In turn, in in Experiment 3, they re-analyzed the fMRI data collected by Vartanian et al. (2013) by conducting parametric analyses that enabled them to compute the covariation between brain activation and variation in scores on each of those three dimensions. The results demonstrated that dissociable regions within the visual cortex exhibited covariation to Coherence, Fascination, and Hominess scores, thereby suggesting that those regions might be differentially sensitive to those psychological dimensions.

1.1.3 Present experiment

Recall that based on a subset of 80 stimuli from Vartanian et al. (2013), Palumbo et al. (2020) had collected data from neurotypical controls, persons with autism spectrum disorder, and university-level design students on two tasks: Liking judgments and approach-avoidance decisions. Based on the research subsequently conducted by Coburn et al. (2020), we had access to PCA-derived scores for Coherence, Fascination, and Hominess for each of those 80 stimuli. Using Palumbo et al.'s (2020) data, this enabled us to test the hypothesis that Coherence, Fascination, and Hominess exhibit different levels of influence on liking judgments and approach-avoidance decisions in the three populations. Specifically, we predicted that due to formal training in architecture and design, university-level design students should be most influenced by Coherence in their choices, given that this factor is directly relevant to assessments of the structural organization of spaces, and informed by formal training. Next, regarding persons with autism spectrum disorder, Asada and colleagues (2016) had measured the preferred distances when persons with autism spectrum disorder and neurotypical controls approached other people and objects. They found that the former group exhibited reduced interpersonal space with other individuals, and also preferred reduced distance from objects, demonstrating that persons with autism spectrum disorder have a relatively small sense of personal and physical space. Atypical *proxemics*—defined as the amount of space one needs for social relationships, communication, and social interaction—might suggest that individuals with autism would need an adequate space for social relationships so as to feel protected and secure (Sánchez, Vázquez, & Serrano, 2011). As such, we predicted that Hominess would be a particularly salient factor in driving choices in this population because it references the extent to which a space feels personal. Finally, regarding neurotypical controls, we predicted that all three factors will determine choices, thereby replicating the main finding from Coburn et al. (2020) based on data from two large convenience samples.

2.1 Method

The data for this study were collected by Palumbo et al. (2020) in the context of a larger study involving additional non-architectural stimuli. Here we will only describe the method relevant to the present analysis.

2.1.1 Participants

The data from persons with autism spectrum disorder and neurotypical controls were collected in the UK. That portion of data collection was approved by the Ethics Committee of Liverpool Hope University, as well as by the Access Review Group of Autism Together. The study was conducted in accordance with the British Psychological Society (BPS) Code of Practice. Data from university-level design experts were collected in Italy. That portion of data collection was approved by the Ethics Committee of IUAV University of Venice, and conducted in accordance with the Declaration of Helsinki (1964) and the ethical principles of APA (American Psychological Association). A power analysis conducted in G*Power (Faul et al., 2009) had determined an actual power of .96-.97 for testing the hypotheses under consideration in Palumbo et al. (2020). However, given the different design used in Coburn et al. (2020), we did not have the appropriate effect size statistic for computing minimum sample size a priori for the present analysis.

Autism spectrum Participants. Sixteen participants with autism spectrum disorder voluntarily took part in the experiment (age range: 19-49, age mean: 28.4 years, 4 females). They were recruited through a collaboration with Autism Together, a charity providing services for individuals with autism based in the North West of England. They had undergraduate education, and were from a low-middle socio-economic background area. All participants had received a diagnosis of High Functioning Autism or Asperger's syndrome from a clinical psychologist or psychiatrist based on DSM-IV-TR (APA, 2004) or ICD-10 (WHO, 2008) criteria. All individuals completed the Autism Spectrum Quotient questionnaire (AQ) (Baron-Cohen et al., 2001), which is a fifty-statement, self-administered questionnaire, designed to measure the degree to which an adult with normal intelligence possesses autistic-like traits. The group had a mean AQ score of 32.2 (*SD* = 7.3). Their mean total IQ score was 97.4 (*SD* = 12.1), assessed using the Wechsler Adult Intelligence Scale, WAIS-III (Wechsler, 1997).

Neurotypical controls. Twenty participants voluntarily took part in the experiment (age range: 20-52, age mean: 24.5 years, 7 females). None of the participants, upon request, reported to have experienced brain injury or to have received a diagnosis of any mental health or developmental disorder. This group consisted of individuals from the general population with GCSE/A levels undergraduate degrees and low-middle socio-economic background so as to match the demographic characteristics of persons with autism spectrum disorder. This group had a mean AQ score of 13.6 (*SD* = 7.1) and a mean total IQ score of 103.2 (*SD* = 6.7). It did not differ from the autism spectrum disorder in terms of age ($t[34] = 1.62$, $p = .11$, $d = -.54$, CLSE = .65; 95% CI = –1.21 [lower] - .13 [upper]), gender ratio ($X^2[1,35] = .42$, $p = .72$, Fisher's exact test, Phi w = .11, Cramer's v = .15. 95% CI = –.31 [lower] - .11 [upper]), or IQ ($t[34] = -1.71$, $p = .10$, $d = -.61$, CLSE = .67; 95% CI = –.07 [lower] - 1.28 [upper]), with equal variance not assumed. As expected, AQ scores were significantly higher in the autism spectrum disorder group than neurotypical controls ($t[34] = 7.74$, $p < .001$, $d = -2.60$, CLSE = .97; 95% CI = –3.487 [lower] - –1.707 [upper]).

Design quasi-experts. Twenty-four university-level students of design voluntarily took part in the experiment (age range: 20-27, age mean: 22.7 years, 2 females). The design students consisted of 11 undergraduates and 13 Master's level students enrolled in courses in the Department of Architecture and Arts at the IUAV University of Venice. The undergraduate students were registered in a course on industrial design and multimedia, with a focus on product and visual design. In turn, the Master's students were registered in a course on product design and communication. Both curricula were part of the same design strand within the Department of Architecture. Both groups of design students took part in this study on a voluntary basis, and did not receive any course credit or compensation for their participation. In addition, all the students were administered the AQ (*M* = 20.04, *SD* = 4.25). As predicted, the average AQ score was significantly lower in design students than in participants with autism spectrum disorder, $t(38) = 6.69$, $p < .00001$, $d = 2.16$.

2.1.2 Materials

The images of interior design were a selection of 80 coloured photographs of architectural interior spaces out of a total of 200 images used originally in Vartanian et al. (2013). Half of the photographs were used in the liking task and the other half in the approach-avoidance task. Half of the spaces presented a rectilinear appearance and the other half a curvilinear appearance. Within each level of appearance, perceived enclosure and ceiling height were also controlled so that within each of the curvilinear and rectilinear sets, there were 5 open high-ceiling images, 5 closed high-ceiling images, 5 open low-ceiling images, and 5 closed low-ceiling images (Figure 1).

2.1.3 Procedures

The procedure involved two tasks: liking and approach/avoidance. Each trial started with a fixation cross which was presented at the centre of the screen for 1500ms. Following that, the stimulus was displayed until response. In the liking task participants indicated whether they liked or disliked each environment by pressing “A” (like) and “L” (dislike) on a keyboard (Figure 2). The response mapping was counterbalanced across participants. In addition, imagining that this were a real room, in the approach/avoidance task participants were asked whether they would like to enter or exit the room by pressing the forward and backward arrows on the keyboard. Two different sets of images were used for the two tasks, therefore none of the environments was ever repeated. The two experimental tasks were counterbalanced across participants and each task involved 8 practice trials, followed by 40 experimental trials presented in random order.[1]

3.1 Results

Using generalized linear mixed effects models (Hox, 2010; Snijders & Bosker, 2012) we analyzed the effects of Coherence, Fascination, and Hominess on responses to liking judgments and approach-avoidance decisions in the three groups. All the statistical analyses were performed using the R environment for statistical computing 4.0.3 (R Core Team, 2020). We used the glmer() function of the lme4 package (1.1-26) (Bates et al., 2015). Model checks were done with the performance package (0.6.1) (Lüdecke et al., 2020) and tables created with sjPlot (2.8.7) (Lüdecke, 2020). Approximation of the degrees of freedom was based on a *ml1* heuristic as suggested by Elff et al. (2020). The data and scripts for data preparation and analyses can be found in https://github.com/gorkang/2020-neuroaesthetics-analysis.

We used the same model structure to analyze how the main effects of Coherence, Hominess and Fascination predict the participants' responses for each group (i.e., participants with autism spectrum disorder, neurotypical controls, university-level design students) and task

[1] Ideally, each individual image would have been presented to half of the participants in one task (e.g., liking judgment) and to the other half of the participants in the other task (e.g., approach-avoidance decisions). Within the neurotypical control and autism spectrum disorder groups, there was a slight imbalance in this assignment. However, this did not affect the nesting within the perceived enclosure, curvature and ceiling height dimensions, nor the mean PCA values for the Coherence, Hominess and Fascination dimensions (all p values > .75, with a median p-value of .94).

(liking judgment, approach-avoidance decisions). All predictor variables were continuous. All models included Coherence, Hominess and Fascination as fixed effects, and random intercepts for item id and participant id. We filtered out those items where participants took more than the mean + 4 SD for that group and task to respond. This amounted to 55 out of a total of 4800 responses.

```
glmer(response ~ coherence + hominess + fascination + (1|participant_id) + (1|image_id),
family = binomial(link = logit), data = DF_analysis,
control = glmerControl(optimizer = "nloptwrap"))
```

3.1.1 Participants with Autism Spectrum Disorder

When predicting liking, the linear mixed effects model revealed significant main effects for Coherence (beta = 1.49, 95% CI [.72, 2.27], $p < .001$) and Hominess (beta = .39, 95% CI [.18, .61], $p < .001$). The effect of Fascination was not statistically significant (beta = .20, 95% CI [–.05, .45], $p = .12$). The model's total explanatory power was moderate (conditional $R^2 = .21$), and the part related to the fixed effects alone (marginal R^2) was .08. In this analysis we filtered out 8 out of 640 (1.25%) responses where reaction time was over the mean + 4 SD (8.98s). Residuals appear to be independent and not autocorrelated ($p = .09$), and there was no multicolinearity between the model variables (Table 1 and Figure 3).

When predicting approach-avoidance decisions, we encountered the same pattern. The model revealed significant main effects for Coherence (beta = 1.92, 95% CI [1.02, 2.82], $p < .001$) and Hominess (beta = .37, 95% CI [.15, .59], $p < .001$). The effect of Fascination was not statistically significant (beta = .08, 95% CI [–.17, .34], p = .53). The model's total explanatory power was moderate (conditional R^2 = .21), and the part related to the fixed effects alone (marginal R^2) was .09. In this analysis we filtered out 6 out of 640 (.94%) responses where reaction time was over mean + 4 SD (8.73s). Residuals appear to be independent and not autocorrelated (p = .61), and there was no multicolinearity between the model variables (Table 1 and Figure 3).

3.1.2 Neurotypical controls

When predicting liking judgments, the model revealed significant main effects for Coherence (beta = 2.17, 95% CI [1.32, 3.02], p < .001) and Fascination (beta = .47, 95% CI [.19, .75], p < .001). The effect of Hominess was not statistically significant (beta = .11, 95% CI [–.10, .32], p = .31). The model's total explanatory power was substantial (conditional R^2 = .30), and the part related to the fixed effects alone (marginal R^2) was .09. In this analysis we filtered out 8 out of 800 (1%) responses where reaction time was over mean + 4 SD (7.08s). Residuals appear to be independent and not autocorrelated (p = .11) and there was no multicolinearity between the model variables (Table 2 and Figure 4).

When predicting approach-avoidance decisions, we encountered the same pattern. The model revealed significant main effects for Coherence (beta = 2.61, 95% CI [1.32, 3.90], p < .001) and Fascination (beta = .364, 95% CI [.01, .72], p = .05). The effect of Hominess was not statistically significant (beta = .07, 95% CI [–.21, .35], p = .63). The model's total explanatory power was substantial (conditional R^2 = .50), and the part related to the fixed effects alone (marginal R^2) was .06. In this analysis we filtered out 10 out of 800 (1.25%) responses where reaction time was over mean + 4 SD (5.19s). Residuals appear to be independent and not autocorrelated (p = 0.83) and there was no multicolinearity between the model variables (Table 2 and Figure 4).

3.1.3 Design quasi-experts

When predicting liking judgments, the mixed model revealed a significant main effect for Coherence only (beta = 2.12, 95% CI [.70, 3.54], p = .003). The effects for Fascination (beta = .13, 95% CI [–.31, .58], p = .56) and Hominess (beta = –.23, 95% CI [–.59, .13], p = .20) did not reach statistical significance. The model's total explanatory power was substantial (conditional R^2 = .40), and the part related to the fixed effects alone (marginal R^2) was of .05. In this analysis we filtered out 11 out of 960 (1.15%) responses where reaction time was over mean + 4 SD (9.23s). Residuals appear to be independent and not autocorrelated (p = .284) and there was no multicolinearity between the model variables (Table 3 and Figure 5).

When predicting approach-avoidance decisions, the same pattern was found. The model revealed a significant main effect for Coherence only (beta = 1.38, 95% CI [.234, 2.53], p = .02). The effects for Fascination (beta = .33, 95% CI [–.04, .70], p = .08) and Hominess (beta = –.02, 95% CI [–.31, .27], p = .89) did not reach statistical significance. The model's total explanatory power was substantial (conditional R^2 = .31), and the part related to the fixed effects alone (marginal R^2) was .03. In this analysis we filtered out 12 out of 960 (1.25%) responses where reaction time was over mean + 4 SD (8.6s). Residuals appear to be independent and not autocorrelated (p = .66) and there was no multicolinearity between the model variables (Table 3 and Figure 5).[2]

4.1 Discussion

[2] The distribution of reaction times (RT) for the rating tasks produced by the three groups appears in Appendix 1.

Coburn et al. (2020) had found that the dimensions of Coherence, Fascination, and Hominess can account for the majority of variance in people's preferences for architectural interiors. Reanalyzing data from Palumbo et al. (2020) using a subset of the same database of images, we tested the hypothesis that the contributions of those three dimensions to preference for architectural interiors would vary as a function of individual differences. Data collected from university-level design students, participants with autism spectrum disorder, and neurotypical controls supported this hypothesis. Specifically, we found that for design students, Coherence was the only factor influencing choice. We suggest that Coherence is paramount for design students because it is directly relevant to assessments of the structural organization of spaces, and is informed by formal training. In this sense, Coherence is a somewhat dispassionate factor, perhaps driven more by cognitive and sensory rather than emotional input.

In contrast, we found that in participants with autism spectrum disorder, preference for architectural interiors was driven by Hominess as well as Coherence. For participants with autism spectrum disorder, we had predicted that Hominess is likely important because of the importance of physical proximity to other people and objects in that population. Specifically, it has been shown that persons with autism spectrum disorder have a relatively restricted sense of personal and physical space, compared to neurotypical controls (Asada et al., 2016). Indeed, a space that facilitates social relationships without being overwhelming is paramount for individuals with autism (Sánchez et al., 2011). Given that Hominess is a reflection of the extent to which a space feels personal, one would indeed expect to observe greater attention given by participants with autism spectrum disorder to this specific dimension. Here it is important to acknowledge that factors other than proxemics could also contribute to the relevance of Hominess as a driver of preference in participants with autism spectrum disorder. For example, ever since Kanner's (1943) foundational work, it has been well-established that persons with autism spectrum disorder prefer familiarity and dislike novelty. Because some of the items that load on Hominess tap into familiarity (e.g., *This room makes me feel at home*), it is possible that the familiarity of spaces was an important driver of preference in this population. Another factor that could be relevant is the ability for mental simulation, also known as episodic future thinking. Specifically, when viewing and rating images of spaces on preference, one's ability to transpose oneself into that space could impact one's assessment of its desirability. Because persons with autism spectrum disorder show impairment in episodic future thinking (see Lind, bowler, & Raber, 2004), this feature might have influenced the formation of their preferences in relation to Hominess as well.

Coherence is also important because individuals with autism show atypicalities in integrating information from the external world and in perceptual organization, although with some variability (Evers et al., 2018; Frith, 2003; Simmons et al., 2009). Therefore, a coherent environment could facilitate the integration of elements in that space for members of this population. Interestingly, Dong and Heylighen (2018) have proposed that central coherence contributes to shaping design expertise in individuals with autism.

Finally, in neurotypical controls, we found that Fascination as well as Coherence contributed to preference for architectural interiors. This finding was unexpected, given that Coburn et al. (2020) had found that Coherence, Fascination, *and* Hominess predict preference in two large convenience samples. In this sense, Hominess' absence was unexpected. It is unclear why Hominess did not play a role in this study. One possibility might be the way in which the images were perceived by the UK sample. Specifically, the stimuli used in this and earlier studies originated from two architectural image databases in Denmark. It might be that the extent to which those images reflected Hominess might have differed between American (Coburn et al., 2020) and UK samples. As such, the difference between the two studies could be an artifact of the stimuli, a possibility that could be studied in the future. In addition, because our sample size and the number of images in this study were smaller than in Coburn et al. (2000), it was likely more difficult in this case to detect effects of smaller size. This might be another explanation for the difference observed regarding Hominess between the two studies.

An important point to remember is that whereas participants with autism spectrum disorder and neurotypical controls were recruited in the UK, the design students who took part in the study were recruited in Italy. Arguably, it is possible that from a cultural perspective, the Italian design students' sensibilities might have differed from those of British participants. Although we cannot rule out this possibility, it is not necessarily true that compared to British participants, Italians would have responded differently to the design features that were manipulated in the original stimulus set. For example, Gómez-Puerto et al. (2018), based on data collected from Oaxaca (Mexico), Bawku (Ghana), and Mallorca (Spain) have demonstrated a preference for curvilinear over rectilinear design in all three locales, and concluded that "preference for curved-contour objects is common across cultures and conjecture that it is a constituent of a natural propensity for aesthetics" (p. 432). Of course, this does not mean that cross-cultural variation is not a concern. Indeed, there is much evidence to suggest that our preferences are also impacted by cultural and social factors (see Mastandrea, 2020), as could have been the case here, and might also explain the divergence of results involving neurotypical controls in this study vs. those derived from online samples recruited for Coburn et al. (2020). Further examination of cultural and social factors as possible sources of variance in architectural preference would be a welcome addition to the literature.

What are the implication of the present findings for our understanding of the drivers of preference for architectural interiors? In a model dubbed the *aesthetic triad*, Chatterje and Vartanian (2014, 2016) reviewed the literature on neuroaesthetics and empirical aesthetics to propose that aesthetic experiences emerge as a function of the interaction between three large-scale neural systems in the brain: Sensory-motor, emotion-valuation, and knowledge-meaning. The sensory-motor system includes structures that support sensation, perception, motor and somatosensory processes. In turn, structures within the emotion-valuation system are involved in the computation of affect, emotion, and reward. Finally, the knowledge-meaning system is primarily involved as an input source for higher-order cultural, contextual, social, and personal factors into aesthetic experiences. Numerous reviews and meta-analyses have provided evidence in support of the idea that these three systems underlie the emergence of aesthetic experiences (Boccia et al., 2015; Brown et al., 2011; Peace et al., 2016; Vartanian & Skov, 2014). In turn, Coburn et al. (2017) adopted the aesthetic triad as a general framework for a neuroscience of architecture, based on the argument that the same three neural systems are likely sufficient for understanding aesthetic experiences in the domain of architecture.

The data presented here contribute to this literature in two ways. First, they strengthen the claim that individual differences play an important role in determining preference (Corradi et al., 2020; Cotter et al., 2017), especially in the domain of architecture (Palumbo et al., 2020;

Vessel et al., 2017). More specifically, they provide new evidence to show that the influence of the dimensions of Coherence, Fascination and Hominess varies as a function of expertise in architecture and design, as well as deviation from neurotypical development in the form of autism spectrum disorder. Second, regarding the aesthetic triad (Chatterje & Vartanian, 2014, 2016), our findings suggest possibilities for testing hypotheses for localizing the systems within which the effects present themselves. For example, it is typically assumed that expertise effects are instantiated in the meaning-knowledge system, whereas the sensory-motor and emotion-valuation systems would be the likely candidates for effects driven by perceptual and affective factors respectively. As such, future work can more closely scrutinize the psychological and neural drivers of individual differences related to Coherence, Fascination, and Hominess in the context of the aesthetic triad.

Arguably an important limitation of our work involves the relatively small sample sizes associated with our three conditions of interest. However, participants with autism spectrum disorder represent what Simonton (2014) has referred to as *significant samples*—groups of participants that offer an important lens into the phenomenon under consideration. It is typically not the case that they can be recruited in equal numbers compared to university undergraduates or online samples, but the insights derived from the data are valuable because they can suggest processes and/or mechanisms the contributions of which can be explored experimentally involving larger samples in subsequent studies. The same can be said about design students, who as quasi-experts represent an intermediate level of expertise between novices and true experts. In this sense, building on the framework proposed by Coburn et al. (2020), the data presented here reinforce the notion that individual differences are important in the formation of preferences for architectural interiors, and suggest specific hypotheses for further examination.

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Table 1. Mixed model results for participants with autism spectrum disorder for liking judgments and approach-avoidance decisions.

	Liking		**Approach**	
Predictors	*beta (95% CI)*	*p*	*beta (95% CI)*	*p*
(Intercept)	-0.72 (-1.35 – -0.10)	**0.02391**	-0.89 (-1.54 – -0.23)	**0.00771**
coherence	1.49 (0.72 – 2.27)	**0.00016**	1.92 (1.02 – 2.82)	**0.00003**
hominess	0.39 (0.18 – 0.61)	**0.00031**	0.37 (0.15 – 0.59)	**0.00100**
fascination	0.20 (-0.05 – 0.45)	0.11709	0.08 (-0.17 – 0.34)	0.53365
N	$16_{\text{participant\_id}}$		$16_{\text{participant\_id}}$	
	$80_{\text{image\_id}}$		$80_{\text{image\_id}}$	
Observations	632		634	
Marginal R^2 / Conditional R^2	0.081 / 0.215		0.091 / 0.206	

Table 2. Mixed model results for neurotypical controls for liking judgments and approach-avoidance decisions.

	Liking		Approach	
Predictors	*beta (95% CI)*	*p*	*beta (95% CI)*	*p*
(Intercept)	-0.66 (-1.32 – 0.00)	0.05104	-0.23 (-1.25 – 0.79)	0.66165
coherence	2.17 (1.32 – 3.02)	**<0.001**	2.61 (1.32 – 3.90)	**0.00007**
hominess	0.11 (-0.10 – 0.32)	0.30853	0.07 (-0.21 – 0.35)	0.62582
fascination	0.47 (0.19 – 0.75)	**0.00109**	0.36 (0.01 – 0.72)	**0.04598**
N	20 participant_id		20 participant_id	
	80 image_id		80 image_id	
Observations	792		790	
Marginal R^2 / Conditional R^2	0.093 / 0.304		0.064 / 0.498	

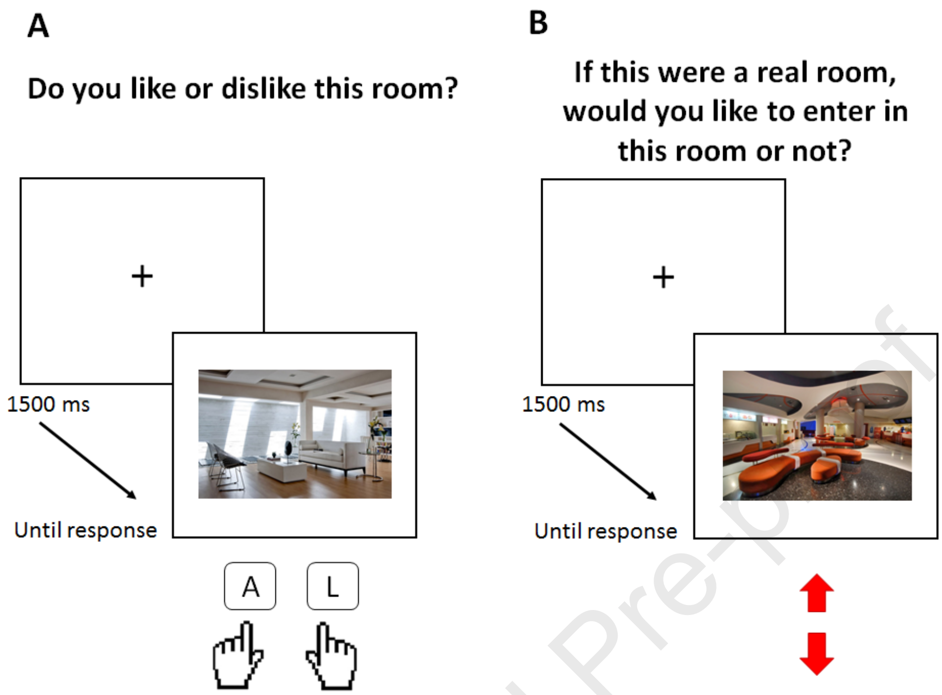
Table 3. Mixed model results for design quasi-experts for liking judgments and approach-avoidance decisions.

	Liking		Approach	
Predictors	*beta (95% CI)*	*p*	*beta (95% CI)*	*p*
(Intercept)	-1.18 (-2.16 – -0.21)	**0.01753**	-0.83 (-1.64 – -0.02)	**0.04398**
coherence	2.12 (0.70 – 3.54)	**0.00346**	1.38 (0.23 – 2.53)	**0.01831**
hominess	-0.23 (-0.59 – 0.13)	0.20166	-0.02 (-0.31 – 0.27)	0.88532
fascination	0.13 (-0.31 – 0.58)	0.55924	0.33 (-0.04 – 0.70)	0.08175
N	24 participant_id		24 participant_id	
	80 image_id		80 image_id	
Observations	949		948	
Marginal R^2 / Conditional R^2	0.048 / 0.403		0.034 / 0.311	

Figure 1. Examples of the experimental stimuli.

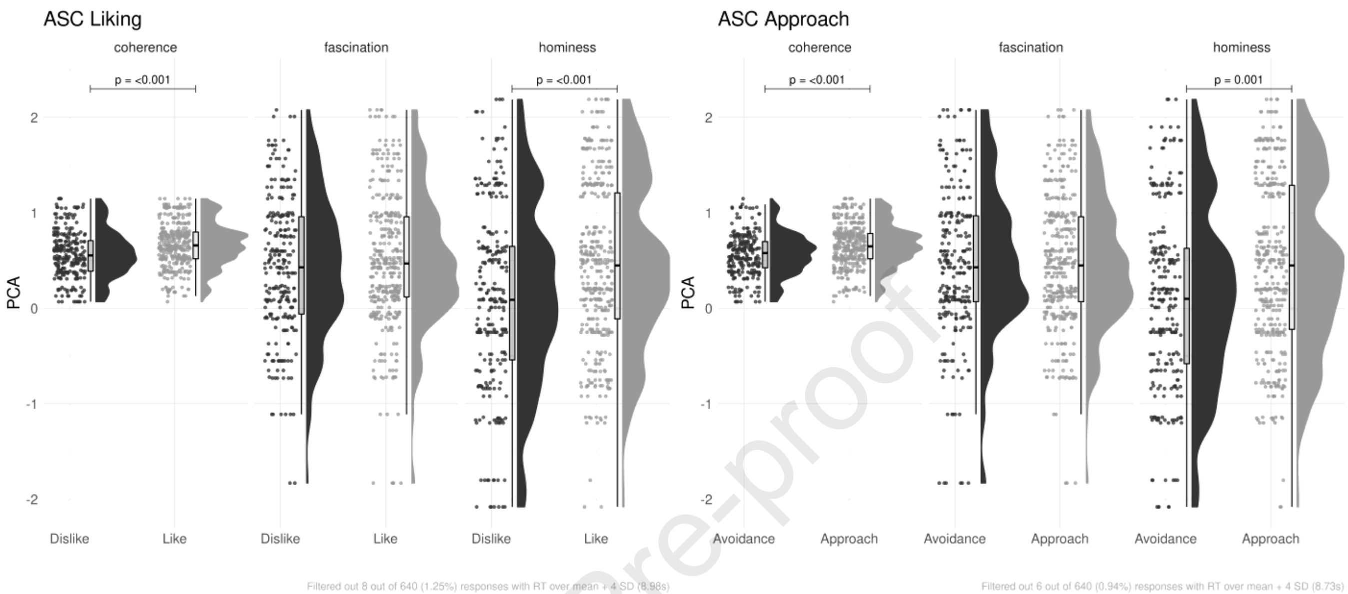
Notes. Image reproduced with permission from Vartanian et al. (2013). The images were balanced in terms of contour (rectilinear vs. curvilinear), ceiling height (high vs. low), and perceived enclosure (open vs. enclosed).

Figure 2. Illustration of the structure of a trial from each of the two tasks: Liking judgment (Panel A) and approach-avoidance decisions (Panel B).



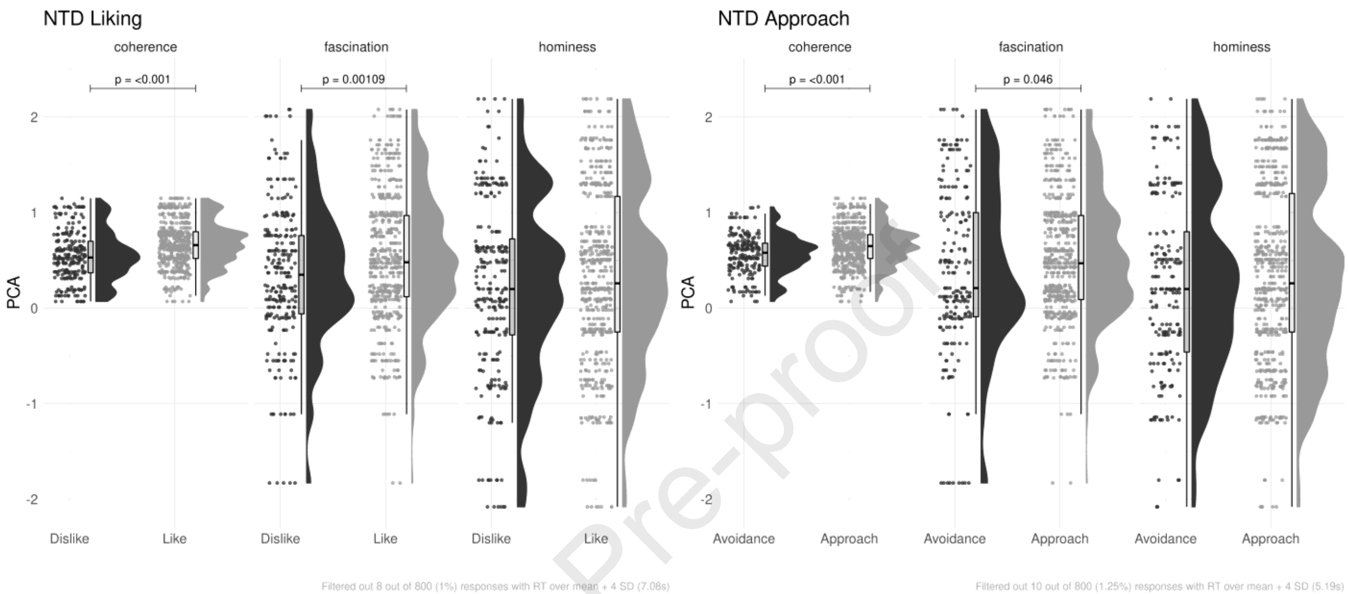
Notes. Reproduced with permission from Palumbo et al. (2020).

Figure 3. Effects of Coherence, Fascination and Hominess on liking judgments and approach-avoidance decisions in participants with autism spectrum disorder.



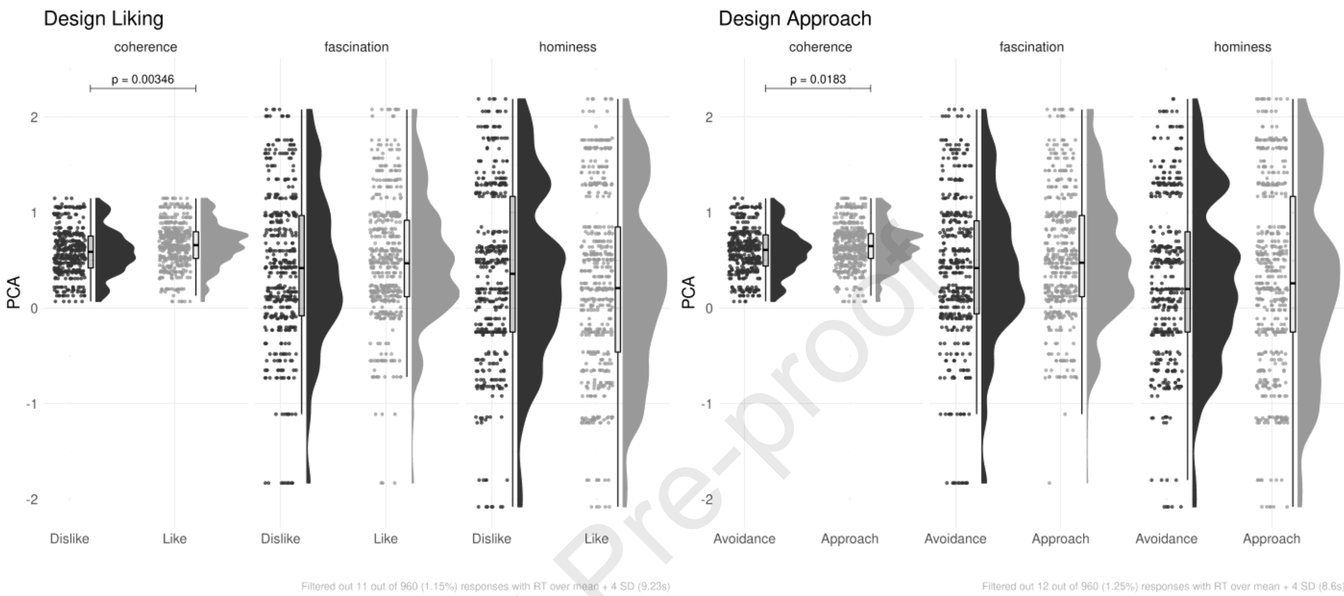
Notes. ASC = autism spectrum condition. The boxplots shown are standard boxplots. The box shows 1st quartile, median, and 3rd quartile. The ends of the whiskers (i.e., vertical lines extending from the top and bottom of the box) show the minimum (Q1 + 1.5*IQR) and maximum (Q3 + 1.5*IQR), beyond which lie the outliers. IQR = interquartile range.

Figure 4. Effects of Coherence, Fascination and Hominess on liking judgments and approach-avoidance decisions in neurotypical controls.



Notes. NTD = neurotypical controls. The boxplots shown are standard boxplots. The box shows 1st quartile, median, and 3rd quartile. The ends of the whiskers (i.e., vertical lines extending from the top and bottom of the box) show the minimum (Q1 + 1.5*IQR) and maximum (Q3 + 1.5*IQR), beyond which lie the outliers. IQR = interquartile range.

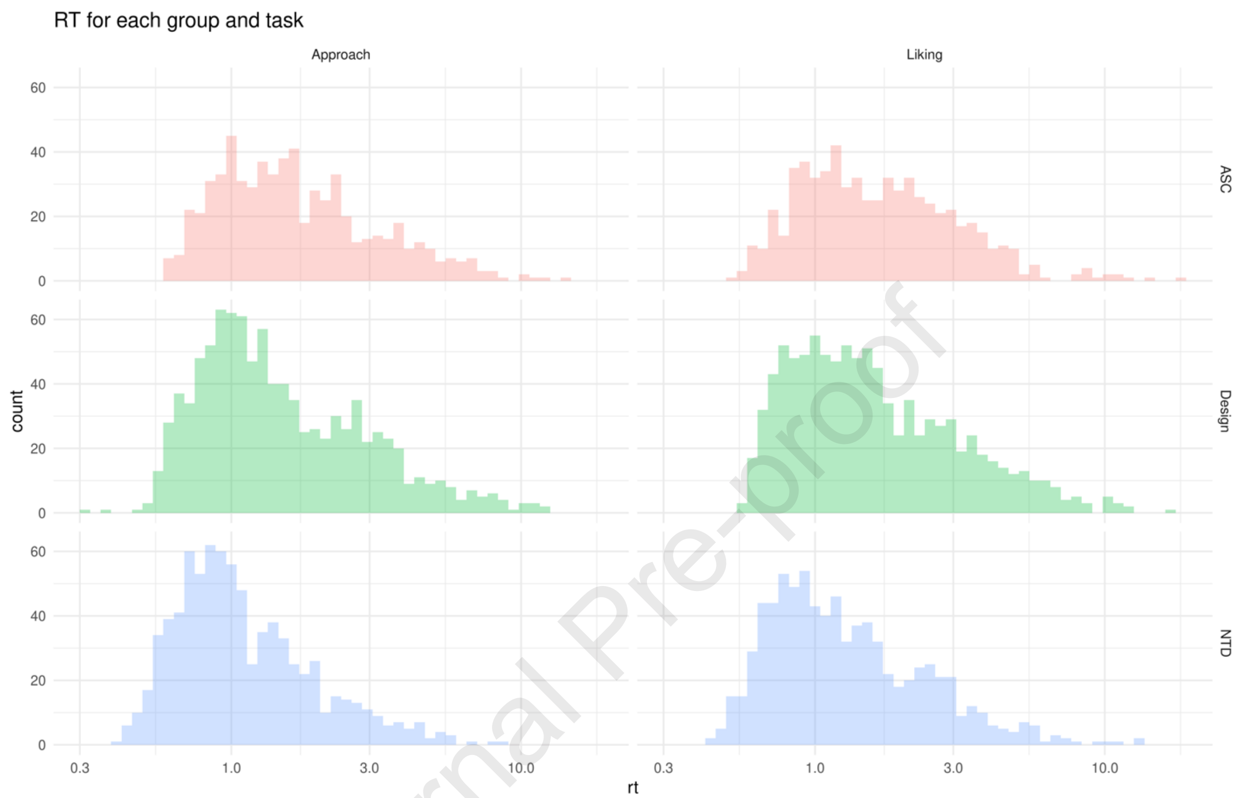
Figure 5. Effects of Coherence, Fascination and Hominess on liking judgments and approach-avoidance decisions in design quasi-experts.



Notes. The boxplots shown are standard boxplots. The box shows 1st quartile, median, and 3rd quartile. The ends of the whiskers (i.e., vertical lines extending from the top and bottom of the box) show the minimum (Q1 + 1.5*IQR) and maximum (Q3 + 1.5*IQR), beyond which lie the outliers. IQR = interquartile range.

Appendix 1

The distribution of reaction times (RT) for the ratings produced by the three groups.



Notes. NTD = neurotypical normal, ASC = Autism Spectrum Disorder.

Table 1. Mixed model results for participants with autism spectrum disorder for liking judgments and approach-avoidance decisions.

	Liking		**Approach**	
Predictors	*beta (95% CI)*	*p*	*beta (95% CI)*	*p*
(Intercept)	-0.72 (-1.35 – -0.10)	**0.02391**	-0.89 (-1.54 – -0.23)	**0.00771**
Coherence	1.49 (0.72 – 2.27)	**0.00016**	1.92 (1.02 – 2.82)	**0.00003**
Hominess	0.39 (0.18 – 0.61)	**0.00031**	0.37 (0.15 – 0.59)	**0.00100**
fascination	0.20 (-0.05 – 0.45)	0.11709	0.08 (-0.17 – 0.34)	0.53365
N	16 $_{participant\_id}$		16 $_{participant\_id}$	
	80 $_{image\_id}$		80 $_{image\_id}$	
Observations	632		634	
Marginal R^2 / Conditional R^2	0.081 / 0.215		0.091 / 0.206	

Table 2. Mixed model results for neurotypical controls for liking judgments and approach-avoidance decisions.

	Liking		**Approach**	
Predictors	*beta (95% CI)*	*p*	*beta (95% CI)*	*p*
(Intercept)	-0.66 (-1.32 – 0.00)	0.05104	-0.23 (-1.25 – 0.79)	0.66165
Coherence	2.17 (1.32 – 3.02)	**<0.001**	2.61 (1.32 – 3.90)	**0.00007**
Hominess	0.11 (-0.10 – 0.32)	0.30853	0.07 (-0.21 – 0.35)	0.62582
Fascination	0.47 (0.19 – 0.75)	**0.00109**	0.36 (0.01 – 0.72)	**0.04598**
N	20 $_{\text{participant\_id}}$		20 $_{\text{participant\_id}}$	
	80 $_{\text{image\_id}}$		80 $_{\text{image\_id}}$	
Observations	792		790	
Marginal R^2 / Conditional R^2	0.093 / 0.304		0.064 / 0.498	

Table 3. Mixed model results for design quasi-experts for liking judgments and approach-avoidance decisions.

	Liking		**Approach**	
Predictors	*beta (95% CI)*	*p*	*beta (95% CI)*	*p*
(Intercept)	-1.18 (-2.16 – -0.21)	**0.01753**	-0.83 (-1.64 – -0.02)	**0.04398**
Coherence	2.12 (0.70 – 3.54)	**0.00346**	1.38 (0.23 – 2.53)	**0.01831**
Hominess	-0.23 (-0.59 – 0.13)	0.20166	-0.02 (-0.31 – 0.27)	0.88532
Fascination	0.13 (-0.31 – 0.58)	0.55924	0.33 (-0.04 – 0.70)	0.08175
N	$24_{\text{participant\_id}}$		$24_{\text{participant\_id}}$	
	$80_{\text{image\_id}}$		$80_{\text{image\_id}}$	
Observations	949		948	
Marginal R^2 / Conditional R^2	0.048 / 0.403		0.034 / 0.311	

- Preference for interior architectural spaces varies among different populations.
- Coherence influenced preferences among all groups that were studied.
- For participants with autism spectrum disorder, Hominess was also relevant.
- For neurotypical controls, Fascination was also relevant.
- For quasi-experts in design, Coherence was the only relevant factor.