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Visual Preference for Abstract Curvature and for Interior Spaces: Beyond Undergraduate Student Samples

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Smoothly curved objects elicit feelings of pleasantness and tend to be preferred over angular objects. Furthermore, individual differences (i.e., art expertise, openness to experience, holistic thinking), and the complexity of the stimuli are known to moderate the effect. We extended the study of individual differences to 2 theoretically relevant groups. Study 1 compared liking for curvature in individuals with autism and a matched neurotypical control group (for age, gender, and IQ). Because preference for curvature depends on both sensory (visuospatial) and affective input, for which individuals with autism exhibit anomalies, we hypothesized a difference in preference for curved stimuli between the 2 groups. Study 2 examined preference for curvature in a group of quasi-expert students of design. Because working architects and designers tend to regard curved interior spaces as beautiful, we hypothesized to replicate this effect within quasi-experts as well, thereby extending the effect across levels of expertise. Using an identical methodology across both studies, we administered abstract stimuli consisting of irregular polygons (angular vs. curved) and patterns of colored lines (angular vs. curved), as well as concrete stimuli consisting of images of interior spaces. Preference for curvature was confirmed with abstract stimuli in all 3 groups. For interior design, the curvature effect diminished in magnitude, and this was especially evident in individuals with autism. Interestingly, quasi-experts preferred rectilinear over curvilinear interiors. We discuss the results in relation to the impact of individual differences and expertise on preference for curvature, and their implication for design studies in ecologically valid settings.

Keywords: visual preference, curvature, interior design, individual differences, autism

Improving the aesthetic qualities of the environment has an impact on our mood, cognitive functioning, behavior, and even mental health (Davies-Cooper et al., 2014; Joye, 2007; Mastandrea et al., 2019). One way to improve the environment is to include more of the features for which we know there is a preference in the general population (Batra et al., 2016). We can see examples of this general approach in architecture and design, such as in the symmetric arrangement of formal gardens surrounding the palace of Versailles.

Along similar lines, preference for smooth curvature, as opposed to angularity, has been reported as a robust effect with familiar objects (Bar & Neta, 2006, 2007), geometric or unfamiliar abstract stimuli (Bertamini et al., 2016; Silvia & Barona, 2009), interior design environments (Leder & Carbon, 2005; Thömmes & Hübner, 2018; Vartanian et al., 2013), and architectural façades (Ruta et al., 2019). This has been replicated using a range of methodologies, such as rating scales, forced choice responses in comparative paradigms or by presenting one stimulus at a time for different durations. It also appears to be unaffected by the type of judgment: liking (Bar & Neta, 2006), beauty (Vartanian et al., 2013), or attractiveness (Palumbo & Bertamini, 2016). However, most empirical research lacks a direct comparison between stimulus types and is restricted to neurotypical individuals (NTD) and university student populations, especially in psychology. Because hedonic evaluations result from the interaction between the visual properties of the objects and the individual characteristics of the

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observers, this interaction is difficult to capture when the type of stimuli is studied separately and within the same population. To address this interaction, the current study investigated the boundary conditions of preference for curvature in two ways. First, we examined the robustness of the phenomenon across simple abstract stimuli and more complex and ecologically valid interior design environments. To our knowledge, the only direct comparison between different types of stimuli was conducted by Corradi et al. (2019) with abstract shapes versus everyday objects. Second, we examined the role of individual differences by looking into two theoretically relevant groups. We focused on persons with autism spectrum condition (ASC) who exhibit anomalies in sensory and affective processes, as well as quasi-experts, in the form of advanced students of design. These groups differ from each other and from the general population in a range of person characteristics (openness to experience and holistic abstract thinking) that are important for curvature preference. Pairing these two samples in the same work using the same methodology allowed us to explore the range of individual characteristics implicated in the curvature effect. Further, using two types of stimuli that differ in terms of complexity, meaning, and therefore familiarity allows one to test whether these dimensions have a stronger or weaker effect on the evaluative process depending on the type of populations studied (i.e., familiarity could have a stronger impact for ASC than for quasi-experts). Briefly, we hypothesized that compared to neurotypical participants, preference for curvature would be altered in persons with ASC but enhanced in quasi-experts in design. The rationale behind our hypotheses is fleshed out below.

Preference for Curvature, Individual Differences, and Art Expertise

As an example of a recent study with abstract shapes, we consider Bertamini et al. (2016). They used unfamiliar irregular polygons with angular or curved contours and abstract patterns, which contained angular, curved, or straight lines. Participants rated liking on a visual scale from 0 (*dislike*) to 100 (*like*). Results confirmed a preference for the curved versions of the stimuli over the angular or straight versions.

Preference for curvature extends to interior design. Vartanian et al. (2013) presented pictures of different interiors varying in contour (curvilinear and rectilinear), perceived enclosure (enclosed and open), and ceiling height (high and low). They asked participants to indicate if the room was beautiful or not beautiful. In a second task, they asked if they wanted to enter the room or not. Participants were more likely to judge spaces as beautiful if they had curvilinear than rectilinear contour. Curvilinear contours activated the anterior cingulate cortex (ACC), which responds to the reward properties and emotional salience of objects. In contrast, contour had no effect on approach-avoidance decisions. More recently, the use of a more realistic setting where participants walked through different exemplars of 3D rooms in a virtual reality (VR) environment confirmed the impact of curvilinear forms on aesthetic preference for architectural spaces (Banaei et al., 2017). The combined use of VR with electrophysiological measures (EEG) revealed a strong effect of curvature geometries on activity in the ACC. Vartanian et al. (2015) also showed that high ceilings and open spaces increase the frequency of "beautiful" responses. In terms of approach, when presented with enclosed spaces participants were more likely to avoid these spaces. The authors concluded that curvilinear appearance of interiors is not the sole aspect that generates appreciation and that there are other dimensions that are relevant for navigating these spaces.

In the current study, we used unfamiliar abstract stimuli (i.e., irregular polygons and patterns of lines) similar to those presented by Bertamini et al. (2016), as well as a subset of the same pictures of living spaces (i.e., interior design environments) used by Vartanian et al. (2013). This allowed us to compare our results with previous reports, and to also compare the magnitude of the preference for curvature effect within the same study. The use of these two different types of stimuli provides a test of the role of meaning and familiarity, which typically influences preference formation (Bonanno & Stillings, 1986; Coupey et al., 1998; Leder & Carbon, 2005). Specifically, by definition the abstract stimuli are unfamiliar, meaningless simple objects, and only vary in terms of contour (angular or curved) rather than semantic content. In contrast, interior design are semantically meaningful and complex stimuli, containing multiple dimensions that can enrich the visual experience leading to preference. It is likely that one's aesthetic appreciation of such images will be influenced by one's earlier experience with spaces that share similar characteristics.

Other studies have reported that the curvature effect overcomes geographical boundaries (Gómez-Puerto et al., 2018, but see Maezawa et al., 2020, for recent data from Japan), occurs across species (Munar et al., 2015), and emerges early in life (Jadva et al., 2010; Quinn et al., 1997). From an evolutionary perspective, such findings suggest that sensitivity to curvature emerged early and could serve an adaptive function. For example, based on neuroimaging data, Bar and Neta (2007) have demonstrated that viewing angular objects activates the amygdala, a structure heavily involved in threat perception. According to their account, humans exhibit a preference for curvature because throughout our evolutionary past angular objects have signaled threat (e.g., sharp rocks), and humans have developed a tendency to avoid them as a result. In contrast, other research has suggested that preference for curvature is not innate or stable but is moderated by the aesthetic zeitgeist of the time (Carbon, 2010). For example, preference for curvilinear forms in car exteriors is evident when the design aesthetic involved building curvilinear cars, but not otherwise.

Recently, Gómez-Puerto et al. (2016) conducted an extensive historical review of various accounts that had been offered to explain this phenomenon. They argued that the proposed accounts could be binned under two categories. First, according to *sensorimotor-based explanations*, the physical properties of curved stimuli directly impact properties of the sensorimotor system. For example, Hubel and Wiesel (1968) identified a set of cells that are sensitive to deviations from continuous straight contours, suggesting that there might be a neurophysiological basis for our sensitivity to curves. More recently, Bertamini et al. (2019) reported an advantage of smooth curvature in processing abstract shapes based on visual properties (i.e., edge orientation) that the visual system integrates. Interestingly, these visual properties seem to resonate with statistical regularities present in the natural environment in which we have evolved (Sigman et al., 2001).

In contrast, according to appraisal-based explanations, humans respond to curvature because of its implicit or explicit effects on the appraisal systems. Curvature incorporates nonrepresentational semantic meaning, which in turn can impact affective responses.

For example, pioneering research dating back almost a century demonstrated that curved lines were perceived as quiet and gentle (Lundholm, 1921), which impacts affective responses to curved stimuli (e.g., Vartanian et al., 2013). Palumbo et al. (2015) found implicit associations between curved abstract shapes and positive semantics, with congruent approach responses for shapes with a smooth contour. Importantly, these two classes of explanations need not be necessarily contradictory, and there is a general consensus in the literature that this phenomenon can be influenced by both evolutionary as well as learning and cultural factors.

Recently, much research has focused on the impact of individual differences as moderators of preference for curvature. For example, liking for curvature can be moderated by art expertise (Silvia & Barona, 2009) and personality. Cotter et al. (2017) conducted a large-scale study where participants rated liking for meaningless abstract stimuli consisting of geometrical figures or irregular polygons, which varied for the type of contour line (curved vs. angular). In addition, a battery of tests was administered including the Aesthetic Fluency Scale (Silvia, 2007, 2013; Swami, 2013), the NEO-Five-Factor Inventory (Costa & McCrae, 1992), and the HEXACO 100 Personality Inventory—Revised (Lee & Ashton, 2004) to assess personality traits. The Types of Intuition Scale was used to measure the ways in which people make decisions and solve problems (Pretz et al., 2014). The authors found that people with art expertise, who are more unconventional, more open to experience and with holistic abstract thinking, tend to find curved shapes as more pleasing. This suggests that aside from a basic propensity to like curvy objects, knowledge, experience and personality play roles as well.

However, results on individual factors have not always been consistent. Corradi, Belman, et al. (2019) compared preference for curvature across two stimuli sets: common use objects and abstract compositions of geometric elements. Curvature was chosen over angularity with both stimuli types, but when controlling for personality traits with the NEO-Five-Factor Inventory (as in Cotter et al., 2017), the authors did not find openness to experience to moderate the effect. Beside some methodological differences, the inconsistency of these results seems to suggest that the contribution of person factors is rather unstable, and it might depend on the target population.

In support of this idea, Vartanian et al. (2019) tested appreciation of curvilinear and rectilinear interior designs with self-identified experts in architecture and design and a group of nonexperts. When judging beauty, the effect of curvilinear designs was only present with the experts. However, on approach/avoidance, the effect was stronger among nonexperts. In a previous study by Dazkir and Read (2012) with students from design and art programs, the advantage of curvilinear designs for approach responses was also found using furniture sets. Therefore, although overall all these studies reported the effect of curvature for more complex stimuli, the results differed depending on participants (expert vs. non expert) and the type of task (liking or approach/avoidance).

Why Examine Preference for Curvature in Autism and in Quasi-Expert Designers?

Here we extend the enquiry about individual differences to persons who had received a prior diagnosis of high functioning autism. The *DSM–5* reports that individuals with autism present a multiple symptomatology within three main areas of impairment: (a) deficits in social communication and interaction; (b) restricted, repetitive patterns of behavior or interests (which includes atypical responses or interest to sensory aspects of the environment); and (c) sensorimotor difficulties (APA, 2013). It is known that individuals with ASC perceive and process information differently (Simmons et al., 2009; Van der Hallen et al., 2018). The majority of studies have focused on theories of global versus local information processing (Booth & Happé, 2018; Happé & Frith, 2006) or enhanced perceptual functioning (Mottron & Burack, 2001; Mottron et al., 2006). However, mixed results have left key aspects unsolved (for a recent meta-analysis, see Van der Hallen et al., 2019). Despite the focus on differences in visual processing, little research has been devoted to visual preference in ASC. It is known that ASC have sensory alterations that may explain why some visual stimuli are experienced as overwhelming or uncomfortable (Ben-Sasson et al., 2009). Some papers have reported that individuals with ASC prefer geometric shapes or objects over social stimuli (Crawford et al., 2016; Pierce et al., 2011; Shi et al., 2015). Individuals with ASC also report difficulties in emotion processing and regulation (Mazefsky et al., 2013; Samson et al., 2012). Preference for simple shapes or lines has been discussed also in relation to emotional responses, that is, pleasantness elicited by the stimuli (Guthrie & Wiener, 1966; Hevner, 1935; Kastl & Child, 1968; Poffenberger & Barrows, 1924).

To our knowledge, there is only one study that examined emotional responses for curvature as opposed to angularity in ASC (Belin et al., 2017). Belin et al. presented looming and static versions of stimuli with a smooth or edgy contour line. They used self-evaluation (questionnaires) and direct observation of participants' behavior while viewing the stimuli. Participants with ASC reported positive feelings with jagged-edged stimuli, whereas participants with neurotypical development reported positive feelings with curvilinear shapes. The authors explained this reversed effect found with ASC individuals by referring to their atypical experience of visual information and emotions.

Building on the work conducted by Belin et al. (2017), we opted to explore preference for curvature in ASC participants to better understand the causal mechanisms that underlie the effect. It is known that preference for curvature depends on both sensory (visuospatial) and affective processing (for review, see Gómez-Puerto et al., 2016). At the same time, it is also known that individuals with autism exhibit anomalies in both affective and sensory processing. Regarding the former, individuals with autism exhibit difficulties in emotion recognition (for meta-analysis, see Uljarevic & Hamilton, 2013). From an appraisal perspective, this difficulty might impede their ability to process the relevant implicit and/or explicit semantic emotional cues associated with curvature and angularity, thereby altering their preference for curvature. In addition, it is now known that individuals with autism have difficulty in sensory processing (Robertson & Baron-Cohen, 2017). In a particularly important study, Wang et al. (2015) demonstrated that when observing natural scenes, individuals with autism exhibit an atypical pattern of attention and visual gaze toward stimuli and their features. Specifically, they attend disproportionately to information in the center of the image regardless of the distribution of objects and attend disproportionately to pixe

level saliency (e.g., visual contrast) at the expense of semantic-level saliency.

There is empirical evidence that sharp angles are marked as salient points of 2-D shapes as well as solid objects (De Winter & Wagemans, 2008; Norman et al., 2001). We reasoned that the atypical pattern of sensory processing, specifically regarding attention allocation to salient aspects of the stimuli (e.g., sharp angles), might alter preference for curvature. On the one hand, if angles were perceived as threatening, then individuals with autism might prefer curves. On the other hand, it could also be that because of their emotional and perceptual dysfunctions they do not perceive angles as threatening, and that instead the salient points along the contour facilitate object recognition. Indeed, the work by Belin et al. (2017) reported a positive reaction for edgy stimuli, and we were interested to see whether we could corroborate their results here. Thus, we hypothesized that due to sensory and affective anomalies, although mild in individuals with high functioning autism, they would show an alteration on the preference for curvature as compared to neurotypicals. This hypothesis finds support if we consider some core deficits or person characteristics (i.e., restricted interests; analytic cognitive style) in autism, as well as differences in relation to personality traits, specially openness to experience, which predicts preference for curvature (Cotter et al., 2017). The literature reports that openness to experience correlates negatively with autism symptoms severity (Schwartzman et al., 2016). A negative correlation between autism and openness to experience emerged also in children (Fortenberry et al., 2011). In contrast, openness to experience and adaptable thinking play a decisive role in stimulating designer imagination and creativity (Chang et al., 2014; Meneely & Portillo, 2005).

To expand the breath of individual variability, we further included a group of students with advanced knowledge in design, hence acknowledged as quasi-experts (Kozbelt & Kaufman, 2014; Silvia, 2005), to examine whether the level of art expertise might play a role in preference for curvature. Previous findings suggest that art expertise predicts preference for abstract curvature (Cotter et al., 2017). When expertise is examined in relation to interior design, it has been demonstrated that compared to laypersons, working architects and designers are more likely to regard curved than angular interior spaces as beautiful (Vartanian et al., 2019). However, currently, it is unknown whether the same is true for quasi-experts with some training but not extensive work experience in architecture and design. We hypothesized that advanced students of design would exhibit a preference for curvature for architectural stimuli, thereby enabling us to generalize the effect across both experts and quasi-experts in design.

The Current Studies

In Study 1, we focused on individuals with high functioning autism and we compared their responses with those of a matched (for age, gender, and IQ) control group of neurotypical adults. In Experiment 1a, we used abstract stimuli (shapes and patterns of lines), whereas in Experiment 1b we presented interior design spaces.

In light of Belin et al.'s (2017) study, we expected individuals with high functioning autism to show an altered preference for curved abstract stimuli (irregular polygons and patterns of lines) and interior spaces as compared to the matched control group. In the control group, we expected to find preference for curvature over angularity across the two types of stimuli, hence replicating previous studies with abstract stimuli (Bertamini et al., 2016) and interior design (Vartanian et al., 2013). However, based on Vartanian et al.'s (2019) work, we predicted that preference for curvature of lay participants would be less strong than what we expected to find with quasi-expert designers in Study 2. Finally, from a practical perspective, we hoped that the present work may identify preferred characteristics of living spaces that can inform the design of more autism-friendly environments.

In Study 2, we tested a group of neurotypical participants who undertook undergraduate and postgraduate studies in design. This was to assess whether liking for curvature would also occur with students who have design knowledge and artistic competence to evaluate the stimulus material. Based on previous studies (Cotter et al., 2017; Silvia & Barona, 2009), we predicted preference for curvature over angularity with abstract stimuli (Experiment 2a) as well as with interior design environments with quasi-expert designers (Experiment 2b).

Study 1

Method

To estimate the expected effect size for Experiment 1a using abstract stimuli (shapes and patterns of lines), we referred to Bertamini et al. (2016) where similar stimuli were employed. The average effect size over the two experiments was $\eta_p^2 = .387$ and therefore Cohen's $f = .794$. We used G*Power (Version 3.1.9.4; Faul et al., 2009) and entered this effect size, an alpha of .05, a power of .95. For a repeated-measures analysis of variance (ANOVA) with between-subjects factors involving two groups, the necessary sample size was 12, with an actual power of .96.

To estimate the expected effect size for Experiment 1b a posteriori using images of interior design, we referred to Vartanian et al. (2013) where the same stimuli were used. The power analysis was conducted in G*Power based on a z score $= -2.13$ and $N = 18$, $d = -1.161$, converted to $f = 0.581$, alpha error probability $= .05$, and a power of .95. For a repeated-measures ANOVA with between-subjects factors involving two groups, the necessary sample size was 42, with an actual power of .96. When the required power was reduced to .80, the necessary sample size was 26, with an actual power of .81.

ASC Participants

Sixteen participants voluntarily took part in the experiment (age range = 19–49, M age = 28.4 years; 4 females, 3 left-handed). The ASC group was recruited through the collaboration with Autism Together, a charity providing services for individuals with autism based in the North West of England. The ASC individuals presented undergraduate education level and were from a low-middle socioeconomic background area. All ASC 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, 2000) or ICD-10 (World Health Organization, 2004) criteria. It was not possible to gain further confirmation of diagnostic history for ASC using the ADOS (Autism Diagnostic Observation Schedule). However, all individuals completed the

Autism Spectrum Quotient questionnaire (AQ; Baron-Cohen et al., 2001), which is a 50 statement, self-administered questionnaire, designed to measure the degree to which an adult with normal intelligence possesses autistic-like traits. ASC participants 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 Participants

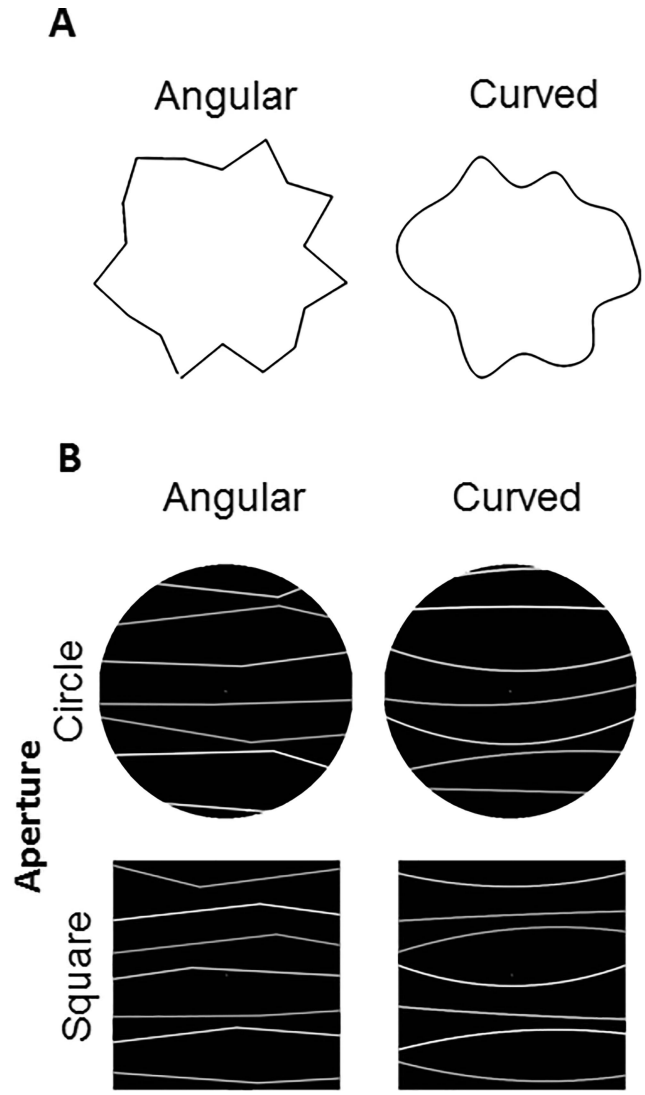
Twenty participants voluntarily took part in the experiment (age range = 20–52 years, M age = 24.5 years; 7 females, 1 left-handed). None of the participants, upon request, reported to have experienced brain injury or to have received a diagnosis of any mental health or developmental disorder. The NTD control group consisted of individuals from the general population with GCSE/A levels undergraduate degrees and low-middle socioeconomic background as to match the demographical characteristics of individuals with autism. The NTD group had a mean AQ score of 13.6 (SD = 7.1) and a mean total IQ score of 103.2 (SD = 6.7). The TD group did not differ from the ASC group in terms of age, $t(34) = 1.62$, $p = .114$, gender ratio, $\chi^2(1,35) = .419$ ($p = .718$, Fisher's exact test), or IQ, $t(34) = -1.71$, $p = .102$, with equal variance not assumed. As expected, AQ scores were significantly higher in the ASC group, $t(34) = 7.74$, $p < .001$. Participants' characteristics by group are reported in Table 1.

All ASC and NTD participants had normal or corrected-to-normal vision. They provided a written informed consent for taking part. Participants were offered a voucher of £10 as reimbursement. The experiment was approved by the Ethics Committee of Liverpool Hope University as well as by the Access Review Group of Autism Together and it was conducted in accordance with the British Psychological Society Code of Practice.

Experiment 1a

Stimuli and Apparatus. Stimuli were presented on a CTX Vl 950T 19" CRT monitor (1,600 × 1,200 at 75Hz). Two types of abstract stimuli were used: irregular polygons and patterns of lines (see Figure 1). The irregular polygons had black contour lines on a white background. The outline was curved or angular (straight edges). Stimuli and experiment were created using Python and PsychoPy (Peirce, 2007). The stimuli were generated starting from polygons that were based on sampling points along a circle (see Bertamini et al., 2016). Each polygon had 18 vertices. For each shape, a cubic spline generated a curve through the vertices, thus transforming the angular vertices in their smoothed version. To exclude possible effects of memory and familiarity each trial used a different stimulus. However, the stimuli were the same across participants. Distance from the screen was approximately 60 cm.

Figure 1
Examples of the Abstract Stimuli



Note. A: Angular and curved irregular polygons. B: Patterns of angular and curved lines with a circled and squared aperture.

The abstract patterns contained seven lines (curved vs. angular) as described in Bertamini et al. (2016). The lines were seen against a black background. The overall shape may be perceived as an aperture showing lines behind. This aperture was a square (400 ×

Table 1
Demographics and Scores on the Autism Quotient and IQ Tests for ASC and NTD

Group	Gender	Age	AQ	IQV	IQP	IQTOT
ASC	4 women	28.4 (7.3)	32.2 (7.3)	102.3 (14.4)	91.9 (11.4)	97.4 (12.1)
NTD	7 women	24.5 (7.2)	13.6 (7.1)	105.0 (8.2)	100.1 (7.7)	103.2 (6.7)

Note. AQ = Autism Quotient; IQV = verbal IQ tests; IQP = performance IQ tests; ISQTOT = total IQ tests; ASC = autism spectrum condition; NTD = neurotypical individuals.

400 pixels) or a circle (400 pixels in diameter). The lines were created by selecting two points, one on the left side and one on the right side of a rectangular region. The rectangle had coordinates between −180 and 180 vertically and between −200 and 200 horizontally starting from the origin that was set at the center of the screen. There was a constraint so that of the seven points at least three were in the upper half (between 1 and 180) and at least three were in the lower half (between −1 and −180). Each pair of points defined a line. The angular stimulus was created by selecting one additional point, which generated an angle on each of the seven lines. Horizontally this additional point was between −100 and 100 pixels as to avoid lining up the angles on top of each other. The curved stimulus was created by drawing a parabola through the three points. All other aspects were identical to the abstract shapes.

Procedure. Participants completed two experimental blocks. They evaluated the abstract shapes in the first block and the patterns of lines in the second block. The presentation order of the two blocks was counterbalanced across participants. The procedure was identical for the two blocks. Each trial started with a fixation cross which was presented at the center of the screen for 1,000 ms. Following that, the stimulus was displayed for 1,500 ms. After the stimulus disappeared, a visual rating scale was presented (0 = *dislike* to 100 = *like*) as shown in Figure 2. Participants expressed how much they liked the stimulus by moving the cursor on the slider with the mouse from left to right (or vice versa) until they endorsed their response with a mouse click. Each block started with 10 practice trials, followed by 40 experimental trials presented in random order within the block. Experiment 1 lasted 20 min.

Experiment 1b

Stimuli and Apparatus. The images of interior design were a selection of 80 colored photographs of architectural interior spaces (Vartanian et al., 2013). The images originated from two architectural image databases at the Department of Architecture, Design, and Media Technology in the University of Aalborg, Denmark, and at The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation. 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, openness and ceiling height were also controlled so that within each of the curvilinear and rectilinear sets, there were five open high-ceiling images, five closed high-ceiling images, five open low-ceiling images, and five closed low-ceiling images (see Figure 3). All the other aspects were identical as for the abstract stimuli.

Procedure. The procedure involved two tasks: liking and approach/avoidance. Each trial started with a fixation cross which was presented at the center of the screen for 1,500 ms. Following that, the stimulus was displayed until response. Participants indicated whether they liked or disliked each environment by pressing "A" (like) and "L" (dislike) on a keyboard (see Figure 4). The response mapping was counterbalanced across participants. In addition, imagining that this were a real room, 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 environment 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. Experiment 2 lasted 20 min.

Participants filled in the AQ questionnaire and the WAIS-III. The administration order of the experiments and the additional tests was counterbalanced across participants. The AQ is a 50-items self-administered test (Baron-Cohen et al., 2001). The questions cover five different domains associated with the autism spectrum: social skills, communication skills, imagination, attention to detail, and attention switching/tolerance of change. Each

Figure 2
Illustration of the Structure of a Trial and the Liking Rating Scale (0 = Dislike *to 100 =* Like*) for the First Two Experimental Blocks: Irregular Polygons (A) and Patterns of Lines (B)*

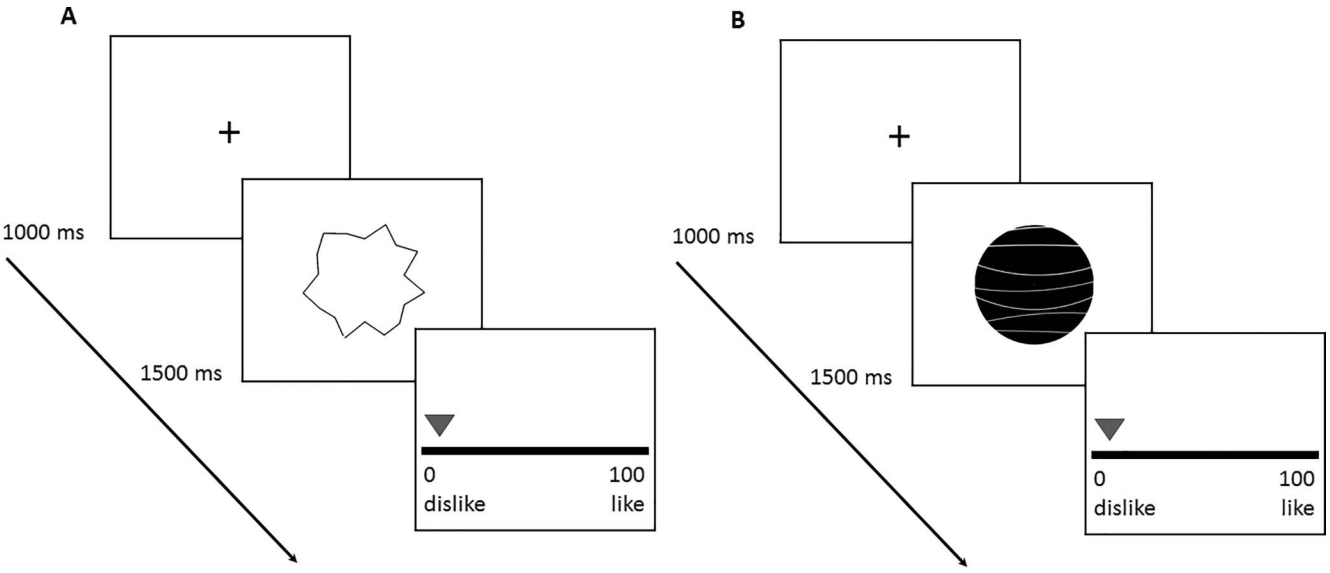
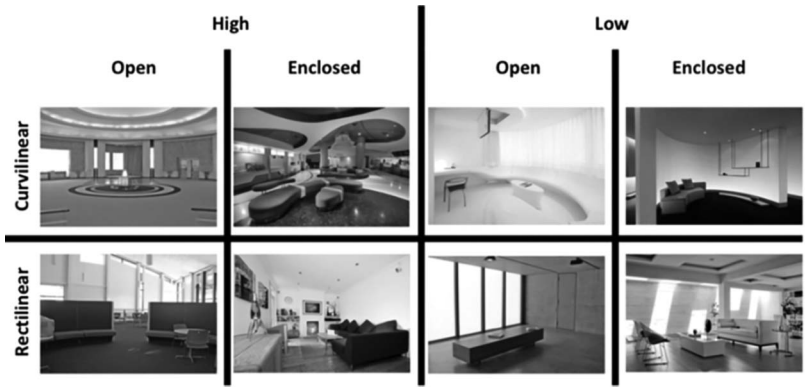


Figure 3

Examples of Curvilinear and Rectilinear Interior Design With Open or Enclosed Space and With High or low Ceiling Height (Image From Vartanian et al., 2013)



statement allows the subject to indicate "definitely agree," "slightly agree," "slightly disagree," or "definitely disagree." It is suitable for the general population. The AQ test is not itself a diagnostic tool but it is reported to discriminate well between individuals with an ASC diagnosis and healthy controls (Baron-Cohen et al., 2001; Booth et al., 2013). A high score (>32 "clinical" threshold and >26 as the "screening" cut-off) on the AQ test has been used to estimate ASC risk and as a guidance for referrals, although with objections (Ashwood et al., 2016).

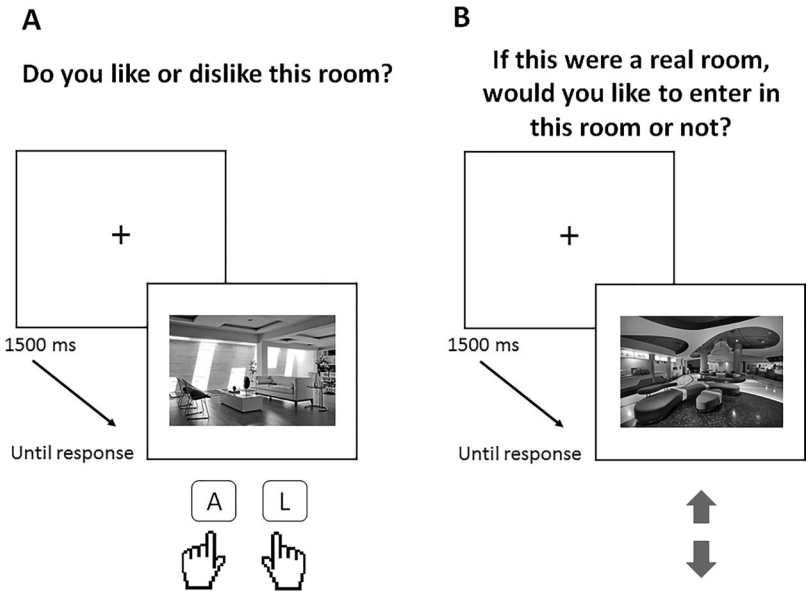
The WAIS-III was administered to assess the level of cognitive functioning of the participants, covering the areas of visual comprehension, perceptual organization and processing speed. The IQ scores were used for screening purposes and were not included in the statistical models. Each participant completed Study 1 within 2 hr and 30 min.

Experimental Design and Data Analysis. We used a mixed design consisting of two separate Experiments (Experiment 1: abstract stimuli; Experiment 2: interior design) and a self-administered questionnaire (AQ).

Experiment 1a. In the first block with irregular polygons we conducted a 2 × 2 × 2 mixed ANOVA with appearance (curved vs. angular) as the within-subjects factor, group (ASC vs. NTD), and experiment order (Experiment 1 vs. Experiment 2) as the between-subjects factors. The dependent variable was the average preference rating on the 0–100 scale. The Greenhouse-Geisser correction was applied if sphericity was not confirmed. We further conducted a correlational analysis for each group of participants to test the relationship between AQ and the difference on preference between curved and angular shapes.

Figure 4

Illustration of the Structure of a Trial and the Two Tasks With Interior Design Stimuli: Like/Dislike (A) and Approach/Avoidance (B)



In the second block with patterns of lines, we conducted a 2 × 2 × 2 × 2 mixed ANOVA with appearance (curved vs. angular) and aperture (circle vs. square) as the within-subjects factors, group (ASC vs. NTD) and experiment order (Experiment 1 vs. Experiment 2) as the between-subjects factor. The dependent variable was the preference rating on the 0–100 scale. The Greenhouse-Geisser correction was applied if sphericity was not confirmed. We further conducted a correlation analysis for each group of participants to test the relationship between AQ and the difference on preference between curved and angular patterns of lines.

Experiment 1b. For the interior design results, we conducted two 2 × 2 × 2 × 2 × 2 ANOVAs, one for like/dislike and the other for approach/avoidance. Each ANOVA included appearance (curvilinear vs. rectilinear), ceiling height (high vs. low), and space (enclosed vs. open) as the within-subjects factors, group (ASC vs. NTD) and experiment order (Experiment 1a vs. Experiment 1b) as the between-subjects factors. The dependent variables were the proportion of "like" responses and the proportion of "approach" responses, respectively. The Greenhouse-Geisser correction was applied if sphericity was not confirmed. We further conducted two correlational analyses for each group of participants. The first analysis tested the relationship between AQ and the difference on liking between curvilinear and rectilinear design spaces. The second analysis examined the relationship between AQ and the difference on approach responses between curvilinear and rectilinear designs.

Results

Experiment 1a

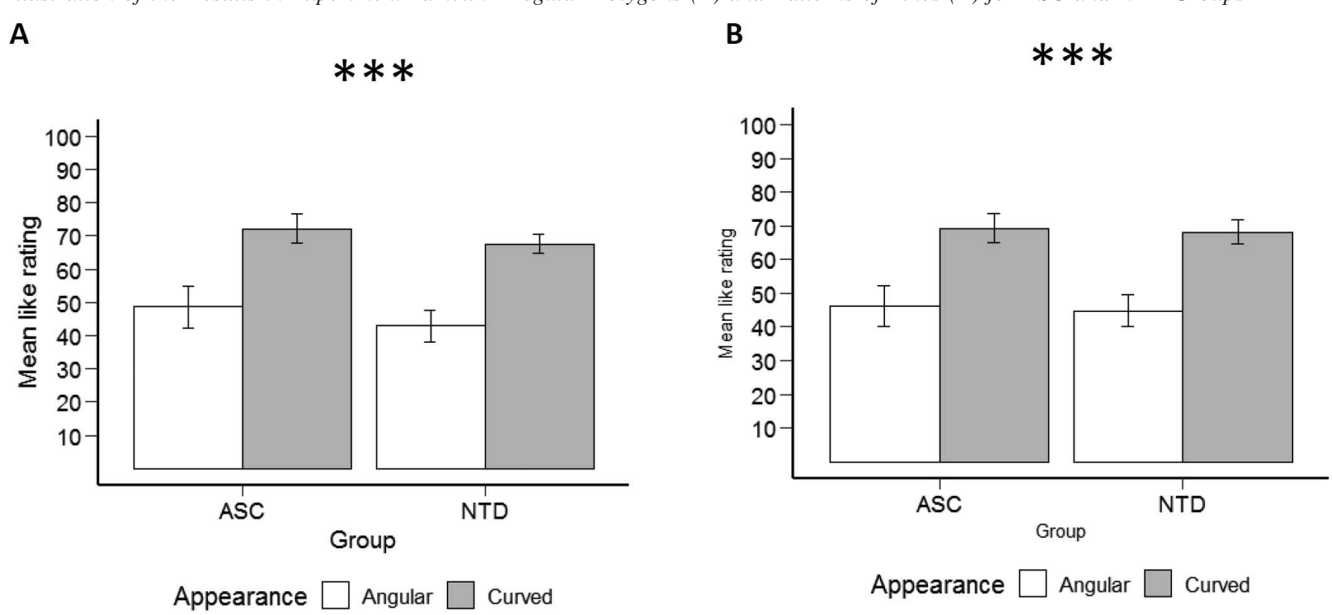
Results of Experiment 1 are reported separately for each block: irregular polygons and patterns of lines. Figure 5 illustrates the results for both types of stimuli.

For the irregular polygons, the ANOVA confirmed a main effect of appearance, $F(1, 32) = 27.35$, $p < .001$, $\eta_p^2 = .461$. Participants liked curved shapes ($M = 69.72$, $SD = 15.12$) more than angular shapes ($M = 45.49$, $SD = 22.81$). This is a strong effect with a mean difference of 24.23. In addition, if we take 50 as the reference (midpoint along the line), curved stimuli tend to be rated above this value and angular stimuli below. The main effect of group was not significant, $F(1, 32) = 1.41$, $p = .243$, $\eta_p^2 = .042$. The main effect of task order was also not significant, $F(1, 32) = .001$, $p = .978$, $\eta_p^2 = .000$. None of the two-way or three-way interactions were significant—Appearance × Group, $F(1, 32) = 0.19$, $p = .890$, $\eta_p^2 = .001$; Appearance × Task order, $F(1, 32) = 2.13$, $p = .155$, $\eta_p^2 = .062$; Group × Task Order, $F(1, 32) = 2.13$, $p = .155$; Appearance × Group × Task Order, $F(1, 32) = 3.16$, $p = .085$, $\eta_p^2 = .090$.

The correlational analysis with the ASC group showed that there was not a relationship between AQ and liking responses for irregular polygons: $R^2 = .134$, $p = .164$. The outcome was similar for the NTD group: $R^2 = .018$, $p = .569$.

For the patterns of lines, the ANOVA confirmed a main effect of curvature, $F(1, 32) = 30.75$, $p < .001$, $\eta_p^2 = .490$. Participants liked curved lines ($M = 68.67$, $SD = 15.69$) more than angular lines ($M = 45.48$, $SD = 21.08$). This strong effect has a mean difference of 23.19. Curved stimuli tend to be rated above 50 and angular stimuli below. There were no other main effects—aperture, $F(1, 32) = .160$, $p = .691$, $\eta_p^2 = .005$; group, $F(1, 32) = .076$, $p = .785$, $\eta_p^2 = .002$; task order, $F(1, 32) = .204$, $p = .654$, $\eta_p^2 = .006$. None of the two-way interactions was significant—Curvature × Group, $F(1, 32) = .001$, $p = .975$, $\eta_p^2 = .000$; Curvature × Task Order, $F(1, 32) = .715$, $p = .404$, $\eta_p^2 = .022$; Aperture × Group, $F(1, 32) = 1.10$, $p = .302$, $\eta_p^2 = .033$; Aperture × Task Order, $F(1, 32) = .892$, $p = .352$, $\eta_p^2 = .027$; Curvature × Aperture, $F(1, 32) = .713$, $p = .405$, $\eta_p^2 = .022$. None

Figure 5
Illustration of the Results in Experiment 1a With Irregular Polygons (A) and Patterns of Lines (B) for ASC and NTD Groups



Note. Error bars indicate *SEM*. ASC = autism spectrum condition; NTD = neurotypical individuals.
*** $p < .001$

of the three-way interactions were significant with the exception of Curvature × Group × Task Order, $F(1, 32) = 4.76$, $p = .037$, $\eta_p^2 = .129$, and Curvature × Aperture × Task Order, $F(1, 32) = 5.75$, $p = .022$, $\eta_p^2 = .152$. However, these comparisons were not significant after Bonferroni correction (all ps $> .05$). No other effects were found (all ps $> .05$).

The correlation analysis with the ASC group showed that there was not a relationship between AQ and liking responses for patterns of lines: $R^2 = .073$, $p = .310$. A similar outcome occurred with the NTD group: $R^2 = .004$, $p = .791$.

Experiment 1b

Results of Experiment 1b are reported separately for each task (like/dislike and approach/avoidance). Figure 6 illustrates the results for interior design in the two tasks.

For the liking task, the ANOVA showed a main effect of appearance, $F(1, 32) = 8.46$, $p = .007$, $\eta_p^2 = .209$, with a higher proportion of "like" responses for rectilinear environments ($M = .68$, $SD = .19$) as compared to curvilinear environments ($M = .59$, $SD = .20$). Interestingly, there was also a two-way interaction of Appearance × Group, $F(1, 32) = 4.52$, $p = .041$, $\eta_p^2 = .124$. Pairwise comparisons revealed that with curvilinear environments the ASC group reported a significant lower proportion of "like" responses ($M = .52$; $SD = .05$) than the NTD group ($M = .67$; $SD = .04$), with $p = .024$, Bonferroni corrected. Finally, there was another interaction between appearance and ceiling, $F(1, 32) = 17.48$, $p < .001$, $\eta_p^2 = .353$. Pairwise comparisons showed that with low ceiling, there was a higher proportion of "like" responses for rectilinear ($M = .72$; $SD = .04$) than curvilinear environments ($M = .54$; $SD = .04$), with $p < .001$, Bonferroni corrected. All the other effects were not significant with ps $> .05$.

The correlational analysis with the ASC group showed that there was not a relationship between AQ and the proportion of liking responses for interior design environments: $R^2 = .011$, $p = .705$. The outcome of the correlational analysis with the NTD was similar: $R^2 = .012$, $p = .645$.

For the approach/avoidance task, the ANOVA confirmed a main effect of group, $F(1, 32) = 5.94$, $p = .021$, $\eta_p^2 = .156$, with a significant lower proportion of approach responses for the ASC group ($M = .60$, $SD = .04$) as compared to the NTD group ($M = .74$, $SD = .04$). There was also a two-way interaction with Appearance × Space, $F(1, 32) = 5.84$, $p = .022$, $\eta_p^2 = .154$. Pairwise comparisons revealed that approach increased toward rectilinear environments when space was open ($M = .74$; $SD = .04$) as compared to when space was enclosed ($M = .63$; $SD = .05$), with $p = .021$, Bonferroni corrected. Finally, there was another interaction with Space × Ceiling, $F(1, 32) = 8.06$, $p = .008$, $\eta_p^2 = .201$. Pairwise comparisons showed that with open space, approach increased toward environments with low ceiling height ($M = .74$; $SD = .03$) as compared to high ceiling height ($M = .64$; $SD = .03$), with $p = .004$, Bonferroni corrected. All the other effects were not significant with ps $> .05$.

The correlational analysis with the ASC group showed that there was not a relationship between AQ and the proportion of approach responses for interior design environments: $R^2 = .002$, $p = .873$. The outcome of the correlational analysis with the NTD was similar: $R^2 = .073$, $p = .247$.

Discussion of Study 1

Study 1 tested whether preference for smooth curvature is present for two classes of stimuli and in two groups of participants: ASC and NTD. In Experiment 1a, we used abstract stimuli (irregular polygons and patterns of lines). We predicted an alteration of preference for curvature in ASC participants, due to their difficulties in sensory and affective processing.

The hypothesis was not confirmed. We found a preference for irregular polygons with a curved contour as compared to an angular contour in both groups. A similar outcome occurred also with patterns of lines. For both types of stimuli, preference for the curved version does not correlate with AQ scores. There was, therefore, no evidence that the autistic traits, at least as measured with this quotient, are associated with the appreciation of smooth curvature.

In Experiment 1b, we used images of interior design spaces. We expected to replicate Vartanian et al.'s (2013) results with NTD participants who showed a preference for curvilinear environments. Moreover, we expected a weaker effect with ASC participants. On the like/dislike task, preference for curvilinear environments appeared absent within both groups of participants, although, as predicted, lack of preference for curvature was more evident with the ASC group. The result with the neurotypical group does not replicate the original work by Vartanian et al. (2013). However, in a more recent investigation (Vartanian et al., 2019), the effect of curvilinear designs on the aesthetics of the environments was not confirmed with naïve participants.

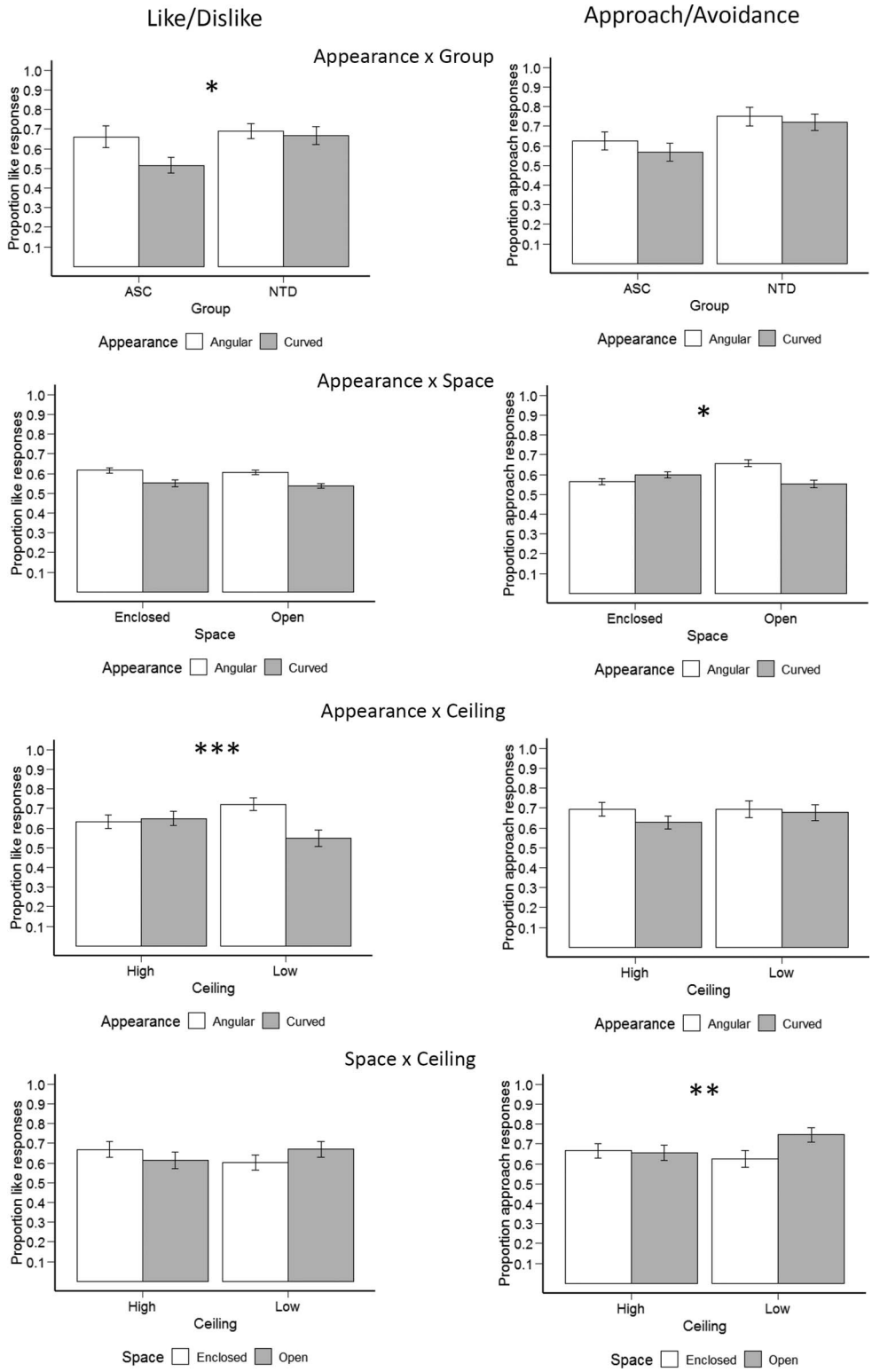
One possible explanation for a diminished preference for curvilinear designs in our study is a familiarity effect. Familiarity has been shown to be relevant for preference formation (Bonanno & Stillings, 1986; Coupey et al., 1998; Leder & Carbon, 2005; Leder et al., 2011), and people are less exposed to curvilinear interiors. Aside from their difficulties in sensory and affective processing, individuals with autism are also averse to unfamiliar situations or novel information (Hodgson et al., 2017; Sterling et al., 2008) and this might suggest that curvilinear interiors are experienced as less pleasant by this group.

Furthermore, the task was self-paced such that the images stayed on screen until response, hence giving familiarity the opportunity to exert its influence over judgment. Corradi, Rosselló-Mir, et al. (2019) found that preference for curved real objects decreased under unlimited viewing times. This effect was explained in terms of a greater influence of the meaning or semantic content on preference. Another possible explanation for the discrepancy between the current results and Vartanian et al.'s (2013, 2019) studies is that they tested mainly female participants, and for the groups of nonexperts those were psychology students. Interestingly, also in the study conducted by Dazkir and Read (2012) participants with art knowledge were predominantly female students. A possible role of gender would need direct verification in future studies.

In our study, we found interaction effects with other dimensions, which are partially in line with previous reports (Vartanian et al., 2015). For the liking task, we found that with low ceiling height, there was a higher proportion of "like" responses for rectilinear than curvilinear environments. It is plausible that when the vertical dimension (ceiling) was reduced, participants were more comfortable with elements made of straight edges, which occupy less space as compared to curvy or circular elements.

Figure 6

Illustration of the Results in Experiment 1b With Interior Design Stimuli for Like/Dislike (Left Column) and Approach/Avoidance (Right Column)



Note. Error bars indicate *SEM*. ASC = autism spectrum condition; NTD = neurotypical individuals.
* $p < .05$. ** $p < .01$. *** $p < .001$

With the approach/avoidance task, the main effect of group indicates that overall individuals with ASC were less likely to approach the stimuli. The difficulty with perspective taking tasks and imagination might have prevented experiencing these photographs as if these were real rooms. Nevertheless, the approach response did not favor the curvilinear environment with ASC as well as with NTD, hence this was in line with the results obtained with the liking task. These results are not in line with Vartanian et al. (2019) as they found more approach responses in favor of curvilinear settings with naïve participants. In addition, when the task involved the execution of an action (enter or exit), we found a series of interaction effects involving the space dimension. First, approach increased toward rectilinear environments when space was open as compared to when space was enclosed. The role of open space was acknowledged by Vartanian et al. (2015), but here it is combined with the presence of rectilinear elements. Second, with open space, approach increased toward environments with low ceiling height as compared to high ceiling height. This suggests that approach is more sensitive to the amount of space available on the horizontal plan (openness of space), rather than the vertical one (ceiling height). An open space with high ceiling height might be perceived as overwhelming. We experience interior design environments on a daily basis, and it is plausible that our preferences reflect how we interact with familiar spaces.

Study 2

Method

Twenty-four quasi-experts in design voluntarily took part in the experiment (age range = 20–27, *M* age = 22.7 years; 2 females, 1 left-handed). The power analysis based on the effect size reported more recently by Vartanian et al. (2019) where participants were experts in architecture and design was conducted in G*Power based on a z score = 5.134 and N = 71 (experts only), d = 1.5368, converted to f = 0.768, alpha error probability = 0.05, and a power of 0.95. For a repeated-measures ANOVA, the necessary sample size was 13 participants, with actual power of .97.

All participants had normal or corrected-to-normal vision and provided a written informed consent for taking part. The experiment was approved by the Ethics Committee of IUAV University of Venice and it was conducted in accordance with the Declaration of Helsinki (1964) and the American Psychological Association ethical principles.

All the other aspects of the method were identical to Study 1 reported above, with the exception that participants did not complete the WAIS-III nor the AQ.

Results

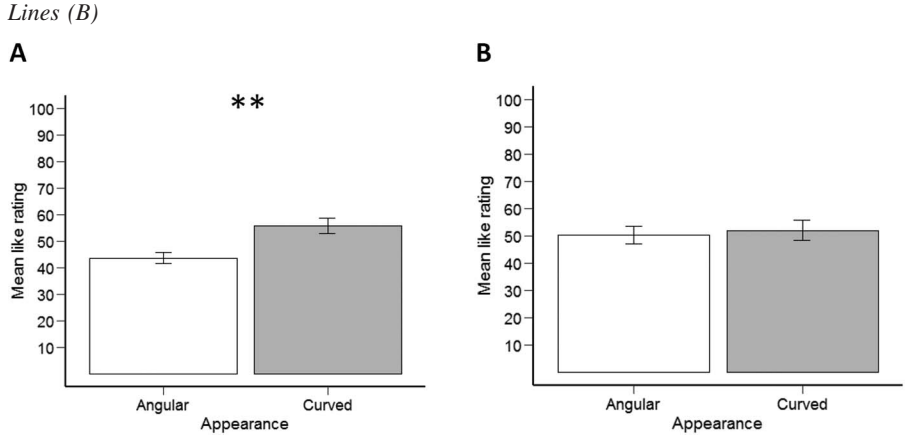
Experiment 2a

Results of Experiment 2a are reported separately for each block: irregular polygons and patterns of lines. Figure 7 illustrates the results with both types of abstract stimuli.

For the irregular polygons, the 2 × 2 ANOVA reported a main effect of Appearance, $F(1, 22) = 8.47$, $p = .008$, $\eta_p^2 = .278$. Participants liked curved shapes ($M = 55.78$, $SD = 13.96$) more than angular shapes ($M = 43.62$, $SD = 9.91$) with a mean difference of 12.16, and with curved stimuli rated above 50 and angular stimuli below. The main effect of task order was not significant, $F(1, 22) = .246$, $p = .625$, $\eta_p^2 = .011$. The interaction Appearance × Task was also not significant, $F(1, 22) = 0.91$, $p = .766$, $\eta_p^2 = .004$.

For the patterns of lines, the 2 × 2 × 2 ANOVA did not confirm a main effect of curvature, $F(1, 22) = .139$, $p = .712$, $\eta_p^2 = .006$. Scores for curved and angular lines were similar (curved: $M = 52.01$, $SD = 14.02$; angular: $M = 50.37$, $SD = 14.70$). There were no other main or interaction effects (multiple comparisons adjusted with Bonferroni reported all ps > .05).

Figure 7
Illustration of the Results in Experiment 2a With Irregular Polygons (A) and Patterns of Lines (B)



Note. Error bars indicate *SEM*.
** $p < .01$.

Experiment 2b

Results of Experiment 2b are reported separately for each task (like/dislike and approach/avoidance). Figure 8 is a comparative illustration of the results with interior design in the two tasks.

For the liking task, the ANOVA reported a main effect of appearance, $F(1, 22) = 4.99$, $p = .036$, $\eta_p^2 = .185$, with a higher proportion of "like" responses for rectilinear environments ($M = .57$, $SD = .17$) as compared to curvilinear environments ($M = .49$, $SD = .18$). The main effect of space was also significant, $F(1, 22) = 10.04$, $p = .004$, $\eta_p^2 = .313$, with a higher proportion of "like" responses for open space ($M = .59$, $SD = .21$) as compared to enclosed space ($M = .46$, $SD = .14$). Finally, there was also a two-way interaction Space × Ceiling, $F(1, 22) = 21.12$, $p < .001$, $\eta_p^2 = .490$. Pairwise comparisons revealed that with enclosed space the proportion of liking responses increased for high ceiling height ($M = .55$, $SD = .36$) than for low ceiling height ($M = .38$, $SD = .36$). All the other effects were not significant with ps $> .05$.

For the approach/avoidance task, the ANOVA confirmed a main effect of appearance, $F(1, 22) = 7.91$, $p = .010$, $\eta_p^2 = .265$, with a higher proportion of "like" responses for rectilinear ($M = .58$, $SD = .15$) as compared to curvilinear environments ($M = .49$, $SD = .18$). The main effect of ceiling was also significant, $F(1, 22) = 11.55$, $p = .003$, $\eta_p^2 = .344$, with a higher proportion of approach responses for high ceiling ($M = .59$, $SD = .16$) as compared to low ceiling ($M = .48$, $SD = .18$). Finally, there was a two-way interaction Space × Ceiling, $F(1, 22) = 7.91$, $p = .010$, $\eta_p^2 = .264$. Pairwise comparisons revealed that with enclosed space the proportion of approach responses increased for high ceiling ($M = .58$, $SD = .36$) than for low ceiling ($M = .41$, $SD = .42$). All other effects were not significant with ps $> .05$.

Discussion of Study 2

Based on past research (Cotter et al., 2017; Vartanian et al., 2013, 2019), we predicted a preference for curvature with abstract stimuli as well as with interior spaces in a group of quasi-expert design students. This was confirmed but with qualifications. The effect of curvature, although weaker, replicated Cotter et al. (2017) for irregular polygons, but it did not emerge with the patterns of lines. It is likely that the compressed range of responses (ratings around 50) found for patterns of lines explain the lack of a significant curvature effect with these stimuli.

The results with interior design revealed a preference for rectilinear environments, hence in the opposite direction compared to the results found by Vartanian et al. (2019). It appears that when curvature is embedded in more complex, multidimensional stimuli, preference might differ and even change direction. Besides the properties of the stimuli, the level of expertise played a role as reflected in the difference found in the response of experts across the studies. Interestingly, this difference occurred only for the appearance (curvilinear vs. rectilinear) of the rooms. For the other dimensions (space and ceiling) there is agreement on the value of high ceiling height and openness of space. It is plausible that the taste and preferences for curvilinear interiors with quasi-experts in the current study is being modulated by training. Our quasi-expert group received specific training in design applied to industrial settings. It is possible that some implicit aspects of their project constraints (i.e., functionality, usability etc.) could have impacted on their perceptual attitude of curvature and its evaluation. This would suggest that preference for curvilinear designs changes as a function of the level of expertise as well as specific knowledge acquired in the discipline.

General Discussion

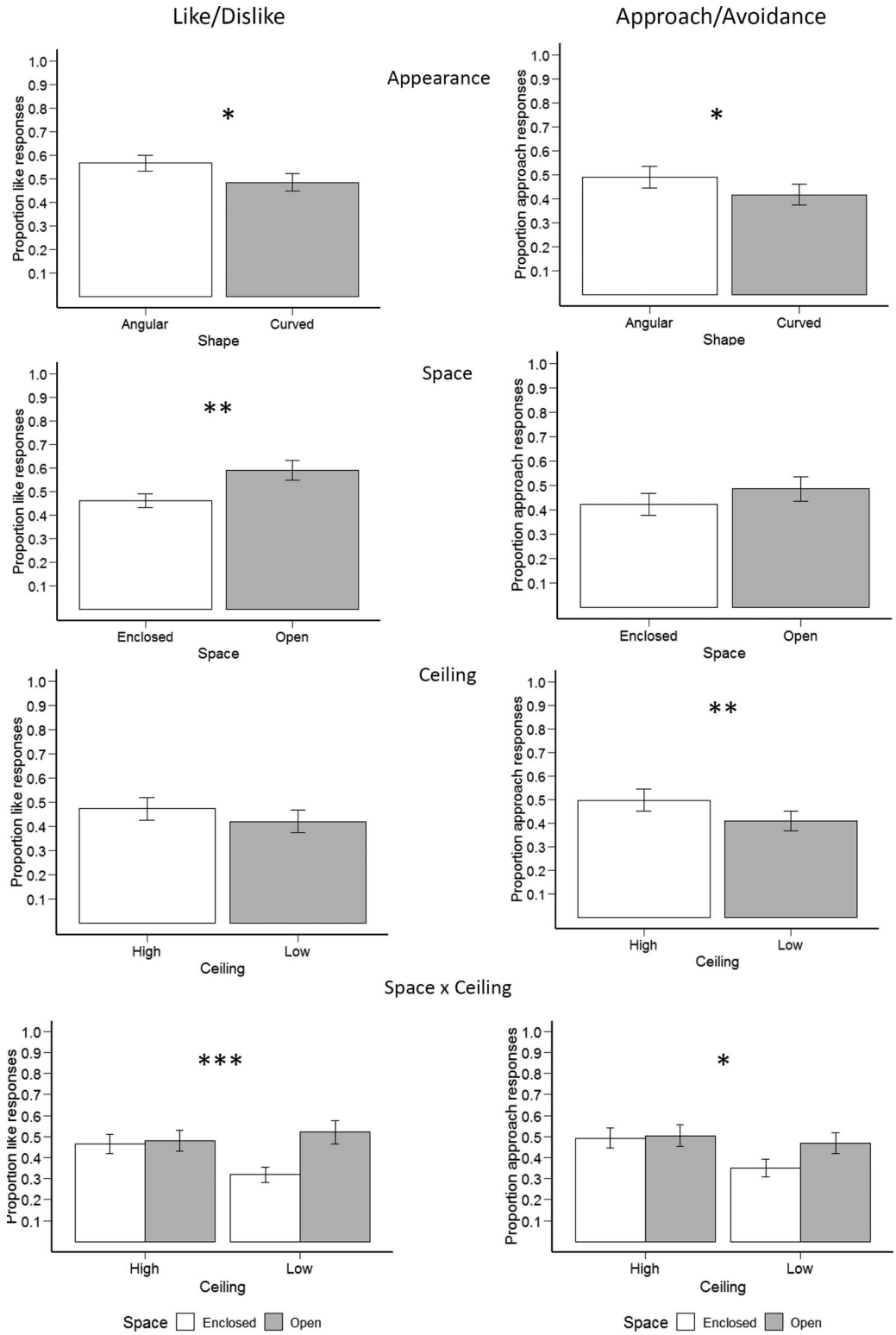
Preference for smooth curvature has been the focus of a large number of studies in the last decade and appears to be a robust effect. Our design involved two key features. First, we included both abstract (i.e., polygons and patterns of lines) as well as ecologically valid stimuli (i.e., room interiors). Second, because preference for curvature also reflects personal characteristics, and given that hedonic responses result from the interaction between the physical properties of the objects and the individual characteristics of the observer, we focused on two theoretically relevant groups (i.e., individuals with ASC and advanced students of design) as well as neurotypical controls. Specially individuals with ASC and designers were paired in the current work because these two populations vary on person factors (e.g., holistic thinking, art expertise, openness to experience) that predict preference for curvature (Cotter et al., 2017). Taken together, our studies confirmed previous research on preference for curvature with abstract simple stimuli (Bar & Neta, 2006; Bertamini et al., 2016; Corradi, Belman, et al., 2019). In contrast, they did not confirm our hypothesis regarding preference for curvature for room interiors, or the predicted enhancement of the magnitude of the effect for quasi-experts in design.

Individuals with ASC preferred curved abstract stimuli as compared to angular stimuli, and the same effect also occurred with the control group. We replicated this result with the group of students of design using irregular polygons (although here there was a floor effect with abstract patterns). Our results with the ASC group are not in line with a previous study (Belin et al., 2017), although differences in terms of the stimuli and tasks do not make these two studies directly comparable. Interestingly, the fact that the curvature effect with abstract stimuli was confirmed in both ASC and designers suggests that individual differences (i.e., openness to experience) and person characteristics (i.e., interests and cognitive adaptability), for which these populations typically differ, did not play a major role in preference formation. This reasoning is applicable also to pictures of interior design, for which, surprisingly, in all the three groups of participants, we found a preference for rectilinear rooms as compared to the curvilinear ones. Specially, with designers this occurred in both the like/dislike and the approach/avoidance task.

When comparing our results with previous reports, we see a discrepancy on the evaluation of the appearance (curvilinear vs. rectilinear) of interior spaces involving various stimuli. In previous studies, a preference for curvilinear spaces was found (Thömmes & Hübner, 2018; Vartanian et al., 2013) with naïve participants, and the effect was even more evident with expert architects and designers but only in the beautiful/not beautiful task (Vartanian et al., 2019). However, there is agreement across the studies on the evaluation of other key aspects of design. In fact, all our participants valued space and ceiling height when expressing appreciation for the interiors, confirming that the preference for curvature in interior design is not absolute but moderated by other features that interact with it.

Figure 8

Illustration of the Results in Experiment 2b With Interior Design Stimuli for Like/Dislike (Left Column) and Approach/Avoidance (Right Column)



Note. Error bars indicate *SEM*.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Why did all the three different groups of participants prefer smooth curvature with the abstract stimuli, but prefer rectilinear environments with interior design? Abstract shapes and patterns of lines are novel, meaningless stimuli. The liking evaluation was based on the manipulation of the type of contour: curved or angular. There was no semantic information available to participants. However, preference for curvature can also be triggered by implicit associations. Previous research has shown that participants automatically associate curved shapes with positive words, and angular shapes with negative words (Palumbo et al., 2015). This is an automatic process that occurs in the absence of conscious control. Hence, preference for abstract curvature emerged equally with ASC, control group, and designers.

In contrast, the evaluation of pictures of interior designs involves more sophisticated processes, grounded on semantic memory and daily experience with interiors. It is known that exposure and familiarity influence preference (Bonanno & Stillings, 1986; Coupey et al., 1998; Hansen & Wänke, 2009; Leder & Carbon, 2005; Leder et al., 2011). People are acquainted with squared rooms and furniture that give a rectilinear appearance to the environment. The relatively greater familiarity with the rectilinear surroundings could have influenced participants' evaluations. This explanation is supported by a significantly weaker preference for curvilinear rooms in the ASC group as compared to the controls. It is known that individuals with ASC experience distress with changes and it is more difficult for them to cope in novel and unfamiliar situations (Hodgson et al., 2017). Although familiarity seems to explain preference for rectilinear environments in ASC, it might not necessarily apply to the same extent with quasi-expert designers. Looking at the program of their courses, the fact that they were specializing in industrial design might better explain their preference for rectilinear spaces. In the case of designers, we speculate that the specific knowledge in the subject area, more than familiarity, could have played a major role. Interestingly, the significance that specific knowledge in degree programs might have on aesthetic evaluations is an aspect to investigate more in relation to art/design expertise.

The difference in the effect of curvature between abstract stimuli and interior spaces can also be explained using recently proposed dual-process models according to which artworks can be processed aesthetically using automatic or controlled processes, with the relative contribution of the two systems determining the depth of aesthetic experience (e.g., Graf & Landwehr, 2015). Specifically, processing performed immediately upon encountering an aesthetic object is likely to be bottom-up and stimulus-driven, giving rise to aesthetic evaluations of pleasure or displeasure. In turn, more elaborate top-down processing can emerge, giving rise to fluency-based aesthetic evaluations (e.g., interest, boredom, confusion). This dual-process model is largely consistent with information-processing models that also predict that more elementary stimulus-driven functions performed on artworks are likely to occur early following exposure, whereas deeper and more elaborate processing occurs later in the information-processing sequence of operations (Chatterjee, 2003; Leder et al., 2004). Given that abstract polygons and line patterns by definition lack semantic content, it is likely that aesthetic responses to them were generated rapidly via bottom-up processes. In contrast, given that images of interior spaces include objects and scenes that can trigger semantic processing, it is likely that aesthetic responses generated in response to them were generated slowly via top-down processes. In this sense, it is possible that although in both cases the task was aesthetic judgment, altogether different information-processing routes were triggered to execute the tasks as a function of the nature of the stimuli, giving rise to divergent findings.

At present, we do not know if the effect of familiarity or exposure can fully explain the results reported by Vartanian et al. (2013, 2019). With nonexpert participants an advantage of curvilinear environment was found with the beautiful/no beautiful task (Vartanian et al., 2013), and with the approach/avoidance task (Vartanian et al., 2019). In Vartanian et al.'s (2019) study experts expressed appreciation for the curvilinear design more than for the rectilinear design. One plausible explanation is that for true experts the curvilinear forms are more challenging and stimulating than rectilinear forms. The impact of cognitive appraisal and interest is central to aesthetic experience (Cupchik & Gebotys, 1990; Fayn et al., 2015; Silvia, 2005). However, under which circumstances familiarity and novelty influence preference is still not well understood. Given these results, at present, we can only speculate that familiarity and novelty might be effective depending on the individuals and the context, including the level of expertise and the specific knowledge in the subject areas.

Furthermore, it should be noted that the NTD control group consisted of individuals from the general population. This allowed extending the results beyond the student population. Importantly, this is the first study testing the effect of curvature on groups of mostly male participants. The results pointed to a preference for angularity, at least for complex ecologically valid stimuli. Interestingly, in a recent (not yet published) study with a balanced number of males and females ($N = 160$), we found that preference for abstract curvature is significantly more evident in female participants, especially in the case of Psychology students. Future research on preference should be more inclusive and extended to children and people with affective disabilities other than autism to explore common patterns that are shared among different groups of participants and also to capture the variability given by individual differences. In this respect, our work communicates that the study of different populations, when supported by theoretically derived predictions is illuminating because it has the potential to expand our understanding the nuances of human preference.

There are some limitations to our study. The first concerns the lack of ADOS scores for the ASC group. Although all participants received previous diagnosis of High Functioning Autism, for which they received support by Autism Together, we do not have a recent update of their conditions. Therefore, the results with the ASC group should be generalized to other high functioning autistic individuals with caution. The second limitation concerns the use of 2D images representing real spaces, especially when the task involves also an action toward these environments. Further research should make use of more controlled stimuli rendered in 3D that can be used in VR environments. Third, our quasi-experts recruited in Italy differed from the ASC and neurotypical groups recruited in the United Kingdom not only in terms of expertise, but also in terms of culture. As such, strictly speaking it is not possible to isolate the effect of expertise from culture in the present study, or in comparison to previous studies involving participants with varying levels of expertise recruited in Canada and Spain (Vartanian et al., 2019). Although preference for curvature has been shown to be present across cultures (Gómez-Puerto et al., 2018), it

is nevertheless important to be mindful of the possible ways in which cultural background might interact with stimulus features and individual differences to drive aesthetic judgment.

Conclusion

We found that preference for curvature with simple abstract stimuli can be replicated across different groups of participants varying in culture, education level, and extent of art/design expertise. In contrast, the effect is not robust for complex and familiar stimuli such as interior design environments. Familiarity and expertise can moderate preference, and with interior environments both factors might have played a role in impacting judgment. This study demonstrated that it is important to examine phenomena of appreciation in heterogenous samples to determine the generalizability of aesthetic phenomena, in this case preference for curvature. A final consideration concerns autism. These results inform existing protocols in design and architecture on the relevance of valuing individual preferences, interests, personal choices and liking. Based on the principle that people function better in places that they like more (Norman, 2002), the integration of these two aspects—functionality and aesthetics—could inform the design of more autism-friendly environments and foster inclusivity.

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