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Aesthetic sensitivity to curvature in real objects and abstract designs

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ABSTRACT

The features of objects have a strong influence on how we evaluate, judge, approach, and behave toward them. People generally prefer complex, symmetric, balanced and curved designs. In addition to these general trends, however, there are substantial differences among people in what they like and prefer, and in the extent to which their preferences and choices are modulated by design features. Here we aimed to determine whether curvature in real objects and abstract designs influenced participants' preference to the same extent. We found that, in general, participants prefer real objects and abstract designs with curved contours. But we also uncovered a remarkable breadth of variation in individual preferences. Finally, our results show that people who are highly sensitive to curvature in real objects are also highly sensitive to curvature in abstract designs, and that people who are insensitive to curvature in one kind of stimulus are also insensitive to the other.

The aspect of objects often determines how we respond to and interact with them. Product and packaging design features influence consumers' attention, evaluation, purchase intentions, and willingness to pay (Bloch, 1995; Patrick, 2016; Ramsoy & Skov, 2014; Reimann, Zaichkowsky, Neuhaus, Bender, & Weber, 2010). Architectonic features, such as ceiling height or openness, impact our affective responses and willingness to enter built environments (Ma, Hu, & Wang, 2015; Vartanian et al., 2013; Vartanian et al., 2015). People's facial features bias others' attitudes, judgments, and behavior toward them (Kampe, Frith, Dolan, & Frith, 2001; Leder, Tinio, Fuchs, & Bohrn, 2010; Mende-Siedlecki, Said, & Todorov, 2012).

Psychological aesthetics aims to provide general explanations for these effects, for the way features of objects shape the way people value them (Berlyne, 1971; Fechner, 1876; Martindale, 2001). Such explanations often rely on general perceptual, cognitive, and affective processes to account for regular and predictable responses to complexity, symmetry, balance, contour, and so on (Leder & Nadal, 2014; Pelowski, Markey, Lauring, & Leder, 2016). For instance, people generally prefer complex, symmetric, balanced, and curved-contour designs (Bertamini, Palumbo, Gheorghes, & Galatsidas, 2016; Höfel & Jacobsen, 2003; Jacobsen & Höfel, 2001; Nadal, Munar, Marty, & Cela-Conde, 2010; Palumbo & Bertamini, 2016; Wilson & Chatterjee, 2005). The explanation for this is that people share common perceptual, cognitive and, affective processes involved in valuation.

The pursuit of general explanations, however, should not overlook individual variation. There are substantial differences among people in what they like and prefer (Jacobsen, 2004; Jacobsen & Höfel, 2002). Some people might prefer simple, asymmetric, unbalanced, or sharp-angled designs. Such variations have been attributed to the effects on valuation of personality (Chamorro-Premuzic, Reimers, Hsu, & Ahmetoglu, 2009; Mastandrea, Bartoli, & Bove, 2009; McManus & Furnham, 2006), intelligence (Chamorro-Premuzic & Furnham, 2004; Furnham & Chamorro-Premuzic, 2004), and expertise (Belke, Leder, Strobach, & Carbon, 2010; Pang, Nadal, Müller, Rosenberg, & Klein, 2013; Silvia & Barona, 2009).

One of the main sources of variation in aesthetic valuation is aesthetic sensitivity. Traditionally, this has been defined as the ability to recognize and appreciate beauty in objects and compositional excellence in art, and to judge artistic merit in accordance with standards of aesthetic value (Child, 1964; Eysenck, 1981; Meier, 1926). Eysenck argued that aesthetic sensitivity was a distinct ability that allowed some people to appreciate objective beauty better than others ("[this ability], independently of intelligence and personality, determines the degree of good or bad taste", Eysenck, 1983, p.231), that it was general because it explained performance on virtually all measures of artistic ability ("it covers a large number of, probably all, pictorial tests", Eysenck, 1940, p. 100), and immutable because it was biologically determined, innate ("[it] presumably [has] a genetic foundation in the structure of the nervous system" (Götz, Borisy, Lynn, & Eysenck, 1979, p. 801), and unalterable through experience ("[it] is independent of teaching,

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tradition, and other irrelevant associations”, Eysenck, 1940, p. 102).

Several tests have been designed to measure aesthetic sensitivity (Barron & Welsh, 1952; Götz et al., 1979; Graves, 1948; Meier & Seashore, 1929). They are all, however, beset with important psychometric problems, including low internal consistency and structural validity, and their scores are explained by intelligence, figural creativity, and personality traits such as conscientiousness extraversion, or openness to experience (Chamorro-Premuzic & Furnham, 2004; Furnham & Chamorro-Premuzic, 2004; Gear, 1986; Myszkowski, Çelik, & Storme, 2018; Myszkowski, Storme, Zenasni, & Lubart, 2014). Rather than a distinct faculty, aesthetic sensitivity seems to draw upon general cognition, learning, and experience.

We have recently argued that these problems reflect two flawed assumptions underlying the concept of aesthetic sensitivity, as it is commonly understood, and the tests designed to measure it (Corradi, Chuquichambi, Barrada, Clemente, and Nadal, submitted): the belief that aesthetic value resides in objects, and the belief that aesthetic value is immutable. We have shown that both of these assumptions are refuted by basic psychological and historical facts. Aesthetic value cannot be considered as an attribute of objects that people are more or less apt at detecting. Aesthetic value is an attribute of people's experience of objects, an experience actively constructed by brain systems that seek to make meaning of those objects, their features, and their value to each person (Corradi, Chuquichambi et al., submitted; Nadal, Gallardo, & Marty, 2017). Moreover, the aesthetic value of any object, whether an artwork or a consumer product, changes with time and perspective; it is historically and culturally relative (Corradi, Chuquichambi et al., submitted; Nadal et al., 2017).

We have introduced a new conception of aesthetic sensitivity that is in line with current understanding of cognitive and neural function. We defined aesthetic sensitivity as the extent to which a given feature influences someone's aesthetic valuation (Corradi, Chuquichambi, et al., submitted). For instance, if the curvature or angularity of objects' contour influences someone's liking or preference for those objects, that person is said to be aesthetically sensitive to curvature. If curvature or angularity does not influence that person's liking or preference, he or she is aesthetically insensitive to curvature.

Aesthetic sensitivity, in this sense, is not equivalent to perceptual sensitivity. Whereas perceptual sensitivity could be understood as the extent to which participants are able to discriminate fine variations in stimulation (e.g. degrees of curvature), we conceive aesthetic sensitivity as the extent to which their preference is influenced or affected by those variations in stimulation. Likewise, aesthetic sensitivity is not equivalent to aesthetic preference, though from this new perspective aesthetic sensitivity is calculated from sets of preference responses. Whereas preference refers to choices that people make, aesthetic sensitivity refers to the extent to which those choices depend on, and are explained by, variations in a certain feature. It is a measure of the degree in which variations in a given stimulus feature have an influence on someone's aesthetic valuation. For instance, when presented with repeated choices between curved or sharp-angled objects, someone who is highly sensitive to curvature would systematically choose one sort over the other. We would say that this person's preference is highly influenced by curvature. Someone who is insensitive to curvature would not choose one sort over the other in a consistent manner. This person might find curvature irrelevant and choose based on other features, or make random choices given that the alternatives are equivalent on relevant features.

This conception of aesthetic sensitivity differs from others (Eysenck, 1940; Meier, 1928) in several aspects. First, it does not rely on the unfounded assumption that aesthetic value is an attribute of objects. Under our conception of aesthetic sensitivity, aesthetic value is a quality of the experience of objects. Second, there is no external normative standard set by any authority: aesthetic sensitivity is the extent to which someone's valuation is responsive to sensory features. Third, aesthetic sensitivity need not be a unitary construct: people might be sensitive to some features but not others. Fourth, aesthetic sensitivity need not be immutable: People's aesthetic sensitivity might be influenced by context, experience, and expertise. Finally, it can be seen as an application of the methods of Social Judgment Theory to the domain of aesthetics (Jacobsen, 2004; Jacobsen & Höfel, 2002). These methods model and compare individuals' judgment policies, that is to say, the relations between individuals' judgments and the cues used to make those judgments (Cooksey, 1996; Hammond, Rohrbaugh, Mumpower, & Adelman, 1977; Stewart, 1988).

Corradi, Chuquichambi et al. (submitted) mapped out the variation inherent to aesthetic sensitivity—as defined in the previous paragraphs—regarding complexity, symmetry, balance, and curvature. They showed that people vary considerably in the extent to which they are sensitive to each of those features. Moreover, they did not find strong correlations among sensitivity to the four features. This supports the notion of aesthetic sensitivity as a multidimensional concept: someone's liking can be strongly determined by one feature but not another.

To test their hypotheses, Corradi, Chuquichambi et al. (submitted) used sets of simple geometrical stimuli. To study aesthetic sensitivity to curvature, for instance, they used 66 patterns half of which had sharp vertices and the other half had curved vertices. Corradi, Chuquichambi et al. (submitted) used only one set of stimuli for each visual feature. Consequently, they could not demonstrate that people's aesthetic sensitivity to any of the features holds for different kinds of objects.

Our main aim in the present study was to determine whether aesthetic sensitivity, in Corradi, Chuquichambi et al. (submitted) sense, holds across different kinds of stimuli. Specifically, we studied aesthetic sensitivity to curvature in real objects and abstract designs. If aesthetic sensitivity to curvature is a personal feature, as we have argued above, people should express similar degrees of sensitivity to the curvature of different kinds of objects. We therefore hypothesized that people who are aesthetically sensitive to the curvature of real objects would also be sensitive to the curvature of abstract designs. Likewise, people who are insensitive to the curvature of real objects would also be insensitive to the curvature of abstract designs.

We had a secondary aim, which was to ascertain whether aesthetic sensitivity to curvature was modulated by art knowledge, sex, and openness to experience. These variables have previously been linked to preference for curvature. Vartanian et al. (2018) found that the curvature of architectural interior spaces had a greater effect on expert architects' beauty ratings than on laypeople's. Cotter, Silvia, Bertamini, Palumbo, and Vartanian (2017) found that art expertise and openness to experience influenced preference for the curvature of certain kinds of objects. Specifically, their results showed that higher levels of art expertise and openness to experience led to greater preference for curved contours. Our inclusion of sex in our analyses was motivated by Bertamini et al.' (2016) suggestion that preference for curvature might have evolved through sexual selection, and by our own prior finding that women preferred curvature to a greater extent than men (Belman et al., 2016).

1. Methods

1.1. Participants

Eighty adult students (M_{age} = 21.6 years, SD_{age} = 2.7 years) attending the University of the Balearic Islands volunteered to participate in the experiment. To test the influence of art expertise on aesthetic sensitivity to curvature, participants were selected on the basis of a criterion: Half of the participants were students of art history, and half studied psychology or education. Each of these groups included equal numbers of men and women. All participants reported normal or corrected to normal vision. Participants were treated in accordance with the Declaration of Helsinki, and the study received ethical approval from the *Committee for Ethics in Research of the Balearic Islands*.

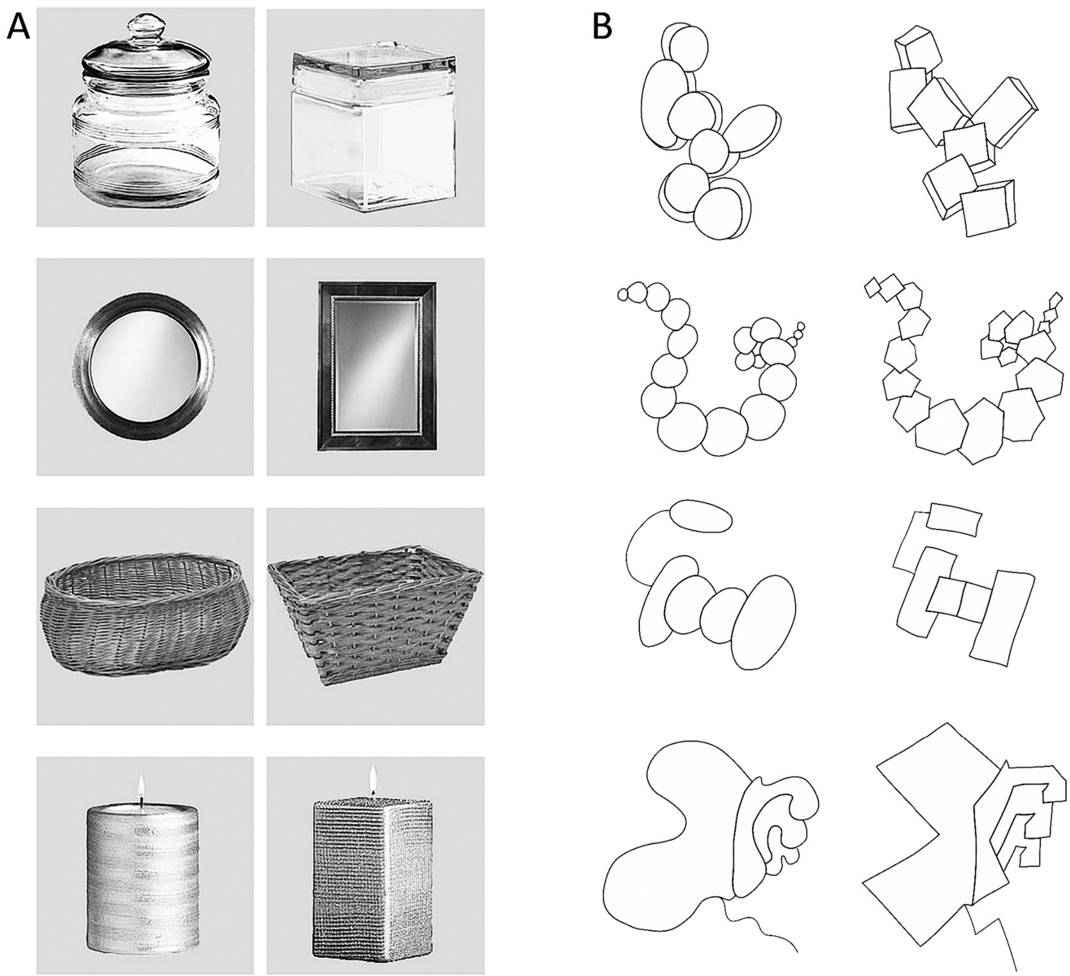

Fig. 1. Examples of the pairs of stimuli in the two sets of stimuli used in this study.
Note. Real objects (A) and abstract designs (B). In each pair the curved version is on the left, and the sharp angled version is on the right.

1.2. Materials

The materials included two sets of images presented on a computer screen and one paper and pencil questionnaire. One of the sets of stimuli contained 36 pairs of images of real objects. This set has previously been used to study preference for curvature (Gómez-Puerto et al., 2018; Munar, Gómez-Puerto, Call, & Nadal, 2015), and is a subset of the stimuli created by Bar and Neta (2006, 2007). The set consists of pairs of objects people interact with in their every day lives: audio and video devices, remote controls, trays, baskets, jars, and so on. Each of the pairs consists of two versions of the same object. One version has curved contours, the other sharp contours (Fig. 1A). The other set contained 36 pairs of images of hand-drawn abstract designs, and was created expressly for this study. In this set, each pair also consists of two versions of the same design, one with curved contours and one with sharp contours (Fig. 1B). All stimuli in all sets were grey scale and displayed on a light grey background. Image sizes were 450 × 450 pixels, presented on a 21″ 1920 × 1080 computer screen placed at approximately 45 cm from participants. After the computer task, participants responded to the 12 items of the openness to experience scale of the NEO-FFI (McCrae & Costa, 2004), and a Spanish translation and adaptation of Chatterjee, Widick, Sternschein, Smith II, and Bromberger's (2010) art training, interest and activities scale. Five of the items asked about interest in art (1. How interested are you in art? 2. How often do you visit art museums or galleries? 3. How often do you look at art magazines or catalogues? 4. How often do you look at art on the Internet? 5. How often do you speak about art with friends or family?), and three about formal education in art (6. How many art history courses did you take during or after high school? 7. How many art creation courses did you take during and after high school? 8. How many hours on average do you spend creating visual art?). Participants were asked to answer each question on a 0–6 Likert scale, where 0 corresponded to *Nothing at all* (1), *Never* (2–5), or *None* (6–8), and 6 corresponded to *Very much* (1), *Once a week* (2), *Very frequently* (3–5), or *6 or more* (6–8).

1.3. Procedure

Participants undertook the experimental tasks at the psychology laboratory. They were first welcomed to the laboratory and briefed about the entire procedure. Each participant was then asked to enter one of the individual sound-attenuated testing cabins, all of which have the same computers, software, and adequate light conditions. In the testing cabin, participants received the same standard verbal and onscreen instructions. They were told they would be seeing pairs of images on the computer screen and that they had to select one of the versions in each pair. Following our previous research on preference for curvature (Gómez-Puerto et al., 2018; Munar et al., 2015), each trial started with a fixation cross shown 500 ms, followed by a pair of stimuli on each side of the screen, separated by 7 cm. As in prior studies using these materials and paradigm (Bar & Neta, 2006, 2007; Gómez-Puerto et al., 2018; Munar et al., 2015), stimuli were displayed for 84 ms and then occluded by two grey squares. Corradi et al. (2019) have shown that this paradigm prevents participants from basing their preference judgments on features other than the objects' contour. Participants responded using the keyboard's arrows, left or right. To simulate approach behavior, the selected image was then shown again twice its previous size for 1000 ms at the center of the screen. Half of the participants completed the block with the real objects first and the abstract designs afterwards, and half of the participants completed the blocks in the inverse order. Each of these blocks consisted of 72 trials performed in succession and without interruption. The last 36 trials in each block showed the same pairs as in the first 36 trials, just that the curved and sharp-angled alternatives switched sides: in each pair, the alternative that was on the right the first time was on the left the second time. The order of the stimuli within each block was randomized for each participant. The openness to experience questionnaire and art scale were administered after participants had finished both preference blocks.

1.4. Data analysis

Following Corradi et al. (2019), participants' responses to stimuli in each block were analyzed by means of linear mixed effects models (Hox, 2010; Snijders & Bosker, 2012). The advantage of this method over ANOVAs is that it accounts simultaneously for the between-subjects and within-subjects effects of the independent variables (Baayen, Davidson, & Bates, 2008). Linear mixed effects models are, thus, well suited to analyze preference responses, given that they often vary from one person to another and also from one object to another (Silvia, 2007). For this reason they are often used in experimental aesthetics (Brieber, Nadal, Leder, & Rosenberg, 2014; Cattaneo et al., 2015; Vartanian et al., 2018).

We modeled choices between real objects and choices between abstract designs separately. Both models were set up to reflect the effect of the main predictors on participants' choices: the curved version or the sharp angled version. Barr, Levy, Scheepers, and Tily (2013) recommended modeling the maximal random effects structure justified by the experimental design. This avoids the loss of power, reduces Type-I error, and enables the generalizability of results to other participants and stimuli. All analyses were carried out within the R environment for statistical computing (R Core Team, 2018), using the *mixed*() function of the ‘afex’ package (Singmann, Bolker, Westfall, & Aust, 2016), with likelihood ratio tests to produce the inferential statistics and *p*-values.

Both models included the interaction between sex (*male*, *female*), expertise (*art students*, *non-art students*), and openness to experience as fixed effects. They also included random intercepts within participants and the slope for contour, expertise, and openness to experience as random effects within stimuli pairs. The categorical predictors (contour and expertise) were sum coded, and the continuous predictor (openness to experience) was centered. Reference levels for the categorical variables were *male* and *art student*.

Although the models described above produce group estimates, the main aim of this study was to understand individual differences in responsiveness to curvature. In the linear mixed effects models this corresponds to the modeled random effect within participants. Following Corradi, Chuquichambi et al. (submitted), after running each model we extracted each participant's value for the proportion of curved alternative choices. This was considered as each participant's aesthetic sensitivity to curvature. Finally, to determine whether aesthetic sensitivity to curvature cuts across real objects and abstract designs, we correlated participants' values obtained in each model.

2. Results

2.1. Sample description

As noted above, participants were recruited with the criterion of being art students or non-art (psychology or education) students. The total sample consisted of 40 participants in each group, with 20 men and 20 women in each. As expected, art students scored higher in the art training, interest and activities scale ($M = 34.38$, $SD = 8.58$) than non-art students ($M = 15.80$, $SD = 8.58$). This difference between the groups was significant, $t = 9.687$, df = 78, $p < .0001$. There were no significant differences in openness to experience between art students ($M = 48.4$, $SD = 5.81$) and non-art students ($M = 47.3$, $SD = 5.52$), $t = 0.868$, df = 78, $p = .388$. There were also no significant differences in age between art students ($M = 21.98$, $SD = 2.58$) and non-art students ($M = 21.23$, $SD = 2.81$), $t = 1.243$, df = 77, $p = .218$.

2.2. Aesthetic sensitivity to real objects

The results of the model for choices between pairs of real objects showed that, overall, participants were more likely to choose the curved alternative than the sharp angled one ($\beta_0 = 0.59$, $z = 3.351$, $p = .0008$). None of the predictors had a significant effect on the likelihood of choosing the curved alternative. The difference between the likelihood of art students choosing the curved alternative ($\beta_0 = 0.56$ [0.50, 0.62]) and the likelihood of non-art students choosing the curved alternative ($\beta_0 = 0.61$ [0.54, 0.68]) did not differ significantly, $\beta = -0.11$, $z = 1.213$, $p = .225$. Men ($\beta_0 = 0.55$ [0.47, 0.61]) and women ($\beta_0 = 0.62$ [0.55, 0.68]) did not differ significantly in the likelihood of choosing the curved alternative, $\beta = -0.14$, $z = 1.575$, $p = .115$. Openness to experience did not influence the likelihood of choosing the curved alternative either $\beta = -0.013$, $z = 0.842$, $p = .400$. None of the interactions among the predictors reached significance (all $ps > 0.083$).

Variation among participants in the effects of curvature represented 75.82% of the variance accounted for by the model. Removal of the random intercept within participants significantly worsened the model fit, $\chi^2 = 387.95$, $df = 1$, $p < .0001$. The estimated individual likelihoods of choosing the curved alternative ranged from 0.26 (indicating a strong preference for sharp angled contours) to 0.91 (indicating a strong preference for curved contours). The mean was 0.57, and the standard deviation was 0.14. The individual likelihoods were normally distributed, according to the Shapiro-Wilk normality test, $W = 0.981$, $p = .264$ (Fig. 2A).

2.3. Aesthetic sensitivity to abstract designs

The results of the model for choices between pairs of abstract designs showed that, overall, participants were more likely to chose the curved alternative than the sharp-angled one ($\beta_0 = 0.60$, $z = 2.566$, $p = .0103$). None of the predictors had a significant effect on the likelihood of choosing the curved alternative. The difference between the likelihood of art students choosing the curved alternative ($\beta_0 = 0.56$ [0.45, 0.66]) and the likelihood of non-art students choosing the curved alternative ($\beta_0 = 0.64$ [0.54, 0.74]) did not differ significantly, $\beta = -0.18$, $z = 1.164$, $p = .245$. Men ($\beta_0 = 0.58$ [0.47, 0.68]) and women ($\beta_0 = 0.62$ [0.51, 0.72]) did not differ significantly in the likelihood of choosing the curved alternative, $\beta = -0.09$, $z = 0.586$, $p = .558$. Openness to experience did not influence the likelihood of choosing the curved alternative either, $\beta = 0.006$, $z = 0.228$, $p = .819$. None of the interactions among the predictors reached significance (all $ps > 0.244$).

Variation among participants in the effects of curvature represented 95.48% of the variance accounted for by the model. Removal of the random intercept within participants significantly worsened the model fit, $\chi^2 = 1229.7$, $df = 1$, $p < .0001$. The estimated individual likelihoods of choosing the curved alternative ranged from 0.05 (indicating a very strong preference for sharp angled contours) to 0.94 (indicating a very strong preference for curved contours). The mean was 0.57, and the standard deviation was 0.24. The individual likelihoods were not normally distributed, according to the Shapiro-Wilk normality test, $W = 0.9622$, $p = .0184$ (Fig. 2B).

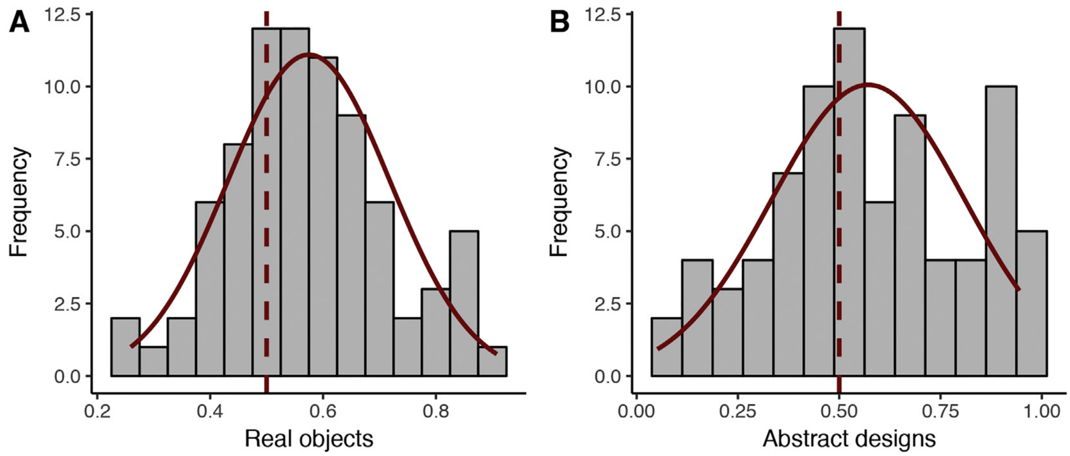

Fig. 2. Distribution of each participant's likelihood of choosing the curved alternative between real objects (A) and abstract designs (B).
Frequency corresponds to the number of participants in each histogram bin. Vertical dashed lines indicate a likelihood of 0.5, meaning absolute indifference toward contour curvature. Likelihoods > 0.5 indicate preference for curved contour stimuli. Likelihoods < 0.5 indicate preference for sharp-angled contour stimuli. Normal curves are overlaid in dark red. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.4. Aesthetic sensitivity to curvature across stimuli kinds

The Spearman correlation between each participant's likelihood of choosing the curved alternative in pairs of real objects and in pairs of abstract designs was $r_s = 0.67$, $p < .0001$ (Fig. 3).

3. Discussion

Aesthetic sensitivity has traditionally been defined as a fixed ability to detect beauty and composition in objects and artworks (Child, 1964; Eysenck, 1981; Meier, 1926). Several tests have been designed to measure aesthetic sensitivity with the intention of aiding the assessment of achievement and vocational guidance (Barron & Welsh, 1952; Götz et al., 1979; Graves, 1948; Meier & Seashore, 1929). In addition to their problematic psychometric properties (Chamorro-Premuzic & Furnham, 2004; Furnham & Chamorro-Premuzic, 2004; Myszkowski et al., 2014; Myszkowski et al., 2018), such instruments are predicated on the flawed assumption that, by virtue of their design, objects and artworks possess a true and immutable aesthetic value.

We have therefore introduced a new conception of aesthetic sensitivity. Corradi, Chuquichambi et al. (submitted) defined aesthetic sensitivity as the extent to which a given feature, such as complexity or balance, influences someone's liking or aesthetic preference. They also showed that people vary considerably in aesthetic sensitivity to complexity, symmetry, curvature, and balance (Corradi, Chuquichambi et al., submitted). It remained to show, however, that people's sensitivity to a given feature holds across kinds of objects. The current study was designed to ascertain whether participants' aesthetic sensitivity to curvature in real objects and abstract designs was the same.

Our results revealed that participants preferably chose the curved alternatives, and this preference was unaffected by their sex, openness to experience, or by whether they were art students or not. This general preference for curvature applied both to real objects and abstract designs: The likelihood of participants choosing the curved alternative in pairs of real objects (0.59) and in pairs of abstract designs (0.60) was almost identical. Moreover, these values are also identical, or almost identical, to those reported in previous studies that have used the same set of pairs of real objects and same paradigm (Corradi, Rosselló-Mir,

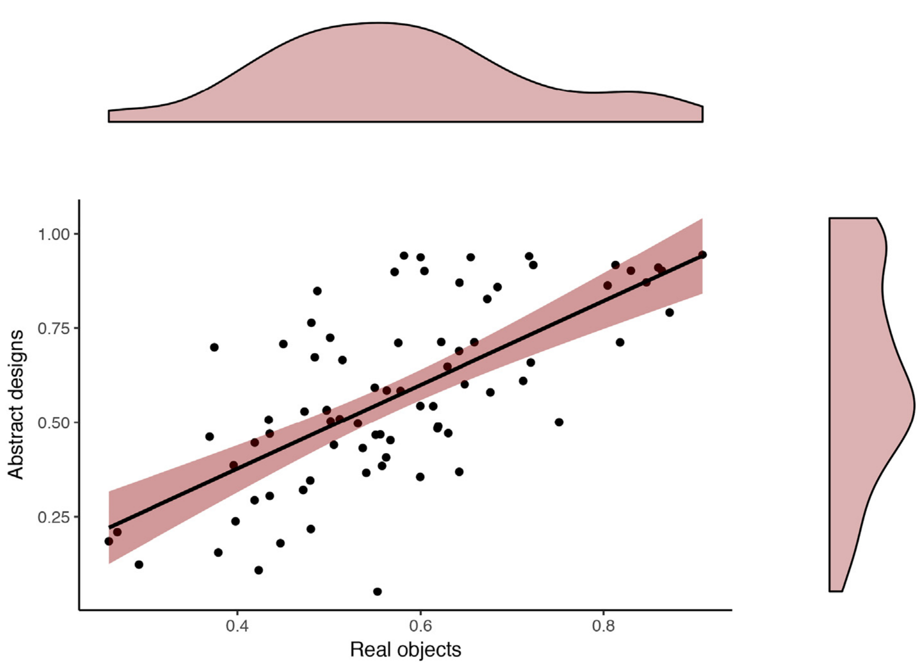

Fig. 3. Correlation between the likelihood of choosing the curved alternative in pairs of real objects and in pairs of abstract designs.
The horizontal axis represents the likelihood of participants choosing the curved alternative when presented with pairs of real objects. The vertical axis represents the likelihood of participants choosing the curved alternative when presented with pairs of abstract designs. The figure includes density plots of likelihood of choosing the curved alternative between pairs of real objects (top) and of choosing the curved alternative between pairs of abstract designs (right).

et al., 2019; Gómez-Puerto et al., 2018; Munar et al., 2015). Our results, thus, replicate those of previous studies, and strengthen the notion of a general preference for curved contours in various classes of objects that extends across experimental paradigms (Palumbo & Bertamini, 2016), across cultures (Gómez-Puerto et al., 2018), and even across species (Munar et al., 2015).

Our primary aim, however, was to ascertain and compare participants' aesthetic sensitivity to curvature in real objects and abstract designs. In this respect, our results uncovered a remarkable range of variation in aesthetic sensitivity to curvature. The likelihood of choosing the curved alternative ranged from 0.26 to 0.91 in real objects, and from 0.05 to 0.94 in abstract designs. This means that whereas some participants consistently chose the curved contour alternatives, others consistently chose the sharp-angled alternatives. To put it another way, our sample included people who were relatively insensitive to curvature in real objects and abstract designs and expressed no consistent preference for curved or sharp-angled contours, people who were very sensitive to curvature and strongly preferred real objects and abstract designs with curved contours, and people who were highly sensitive to curvature but strongly preferred real objects and abstract designs with sharp-angled contours.

Our comparison of aesthetic sensitivity across stimuli sets yielded a very high correlation between participants' aesthetic sensitivity to curvature in real objects and their aesthetic sensitivity to curvature in abstract designs ($r_s = 0.67$). That is to say, participants who preferred curved contours in real objects also preferred them in abstract designs, and participants who preferred sharp-angled contours in real objects also preferred them in abstract designs. These results suggest that aesthetic sensitivity—at least aesthetic sensitivity to curvature—is a personal trait that determines preference independently of whether the objects are real or abstract. This is in line with Cotter et al.' (2017) finding of high correlations in the extent to which participants preferred curved contours in two different sets of regular and irregular polygons.

Our secondary aim was to determine whether aesthetic sensitivity to curvature was moderated by individual differences in sex, openness to experience, and expertise. As noted above, none of these had any effect on the likelihood of choosing the curved contour alternative in real objects or abstract designs. First, we were unable to replicate our prior finding that women were more aesthetically sensitive to curvature than men (Belman et al., 2016). Although the results presented above show that women chose the curved alternative more than men when presented with pairs or real objects (0.62 vs. 0.55) and abstract designs (0.62 vs. 0.58), these differences were not significant. The evidence, therefore, suggests that the difference between women and men in aesthetic sensitivity to curvature is insignificant and unreliable. Second, we found no evidence that openness to experience moderates aesthetic sensitivity. Cotter et al. (2017) had found that openness to experience influenced preference for curvature in irregular polygons but not in regular polygons. They suggested that this might owe to differences in familiarity between both kinds of stimuli. Our results, however, suggest that this might not be the case: we found no influence of openness to experience on preference for curvature in real objects or in unfamiliar abstract designs. Just as for sex, the evidence suggests that the influence of openness to experience on aesthetic sensitivity to curvature is weak or uncertain. Finally, our results do not support the hypothesis that expertise mediates aesthetic sensitivity to curvature. Art students were less sensitive than non-art students to the curvature of real objects (0.56 vs. 0.61) and abstract designs (0.56 vs. 0.64), but these differences were not significant. Vartanian et al. (2018) reported that the curvature of architectural interior spaces had a greater effect on expert architects' beauty ratings than on laypeople's. But Cotter et al. (2017) found only mixed evidence. The reason for this discrepancy might be the correspondence between the field of expertise and the stimuli used. Vartanian et al. (2018) used stimuli that belonged to participants' field of expertise (architects evaluated architectural stimuli). But both Cotter et al. (2017) and ourselves used stimuli that had no specific relation to the field of expertise in a narrow sense (people with greater art knowledge or art students evaluating common objects and abstract designs). Art expertise, thus, might moderate the effect of curvature on preference when the evaluated objects are specific to the field of expertise.

In sum, from a nomothetic approach, our results support the notion of a general trend for people to prefer curved contours in real objects and abstract designs. But from an idiographic approach, our results reveal that people differ considerably in the extent to which, and how, curvature influences their preferences. This discrepancy between both approaches underscores the need for caution when interpreting broad general trends in preference. General trends are often mistakenly assumed to imply uniformity. What does it mean to say that people typically prefer curved contours 59% of the times? How representative is this figure? Curvature affects preferences and choices for mobile devices (Ho, Lu, & Chen, 2016), but does it affect everyone's choices in the same way? Our results suggest that this is not necessarily the case: The general trend to prefer curved contours coexists with a remarkable individual variation in the extent to which people's choices are affected by curvature. The causes of this variation, and its consequences for consumer choice, remain to be elucidated.

Declaration of Competing Interest

The authors have no conflict of interest.

Acknowledgments

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References

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*, 390–412.

Bar, M., & Neta, M. (2006). Humans prefer curved visual objects. *Psychological Science, 17*, 645–648.

Bar, M., & Neta, M. (2007). Visual elements of subjective preference modulate amygdala activation. *Neuropsychologia, 45*, 2191–2200.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68*, 255–278.

Barron, F., & Welsh, G. S. (1952). Artistic perception as a possible factor in personality style: Its measurement by a figure preference test. *The Journal of Psychology, 33*, 199–203.

Belke, B., Leder, H., Strobach, T., & Carbon, C. C. (2010). Cognitive fluency: High-level processing dynamics in art appreciation. *Psychology of Aesthetics, Creativity, and the Arts, 4*, 214–222.

Belman, M., Currò, T., Corradi, G., Nadal, M., Rosselló, J., Del Viva, M. M., & Munar, E. (2016). Explaining individual differences in preference for curvature. *Poster presented at the 24th Conference of the International Association of Empirical Aesthetics. Vienna, Austria*.

Berlyne, D. E. (1971). *Aesthetics and psychobiology.* New York: Appleton-Century-Crofts.

Bertamini, M., Palumbo, L., Gheorghes, T. N., & Galatsidas, M. (2016). Do observers like curvature or do they dislike angularity? *British Journal of Psychology, 107*, 154–178.

Bloch, P. H. (1995). Seeking the ideal form: Product design and consumer response. *Journal of Marketing, 59*, 16–29.

Brieber, D., Nadal, M., Leder, H., & Rosenberg, R. (2014). Art in time and space: Context modulates the relation between art experience and viewing time. *PLoS One, 9*(6), e99019. https://doi.org/10.1371/journal.pone.0099019.

Cattaneo, Z., Lega, C., Ferrari, C., Vecchi, T., Cela-Conde, C. J., Silvanto, J., & Nadal, M. (2015). The role of the lateral occipital cortex in aesthetic appreciation of representational and abstract paintings: A TMS study. *Brain and Cognition, 95*, 44–53.

Chamorro-Premuzic, T., & Furnham, A. (2004). Art judgment: A measure related to both personality and intelligence? *Imagination, Cognition and Personality, 24*, 3–24.

Chamorro-Premuzic, T., Reimers, S., Hsu, A., & Ahmetoglu, G. (2009). Who art thou? Personality predictors of artistic preferences in a large UK sample: The importance of openness. *British Journal of Psychology, 100*, 501–516.

Chatterjee, A., Widick, P., Sternschein, R., Smith, W. B., II, & Bromberger, B. (2010). The assessment of art attributes. *Empirical Studies of the Arts, 28*, 207–222.

Child, I. L. (1964). Observations on the meaning of some measures of esthetic sensitivity.

The Journal of Psychology, 57, 49–64.

Cooksey, R. W. (1996). The methdology of social judgment theory. *Thinking and Reasoning, 2*, 141–173.

Corradi, G., Chuquichambi, E. G., Barrada, J. R., Clemente, A. S., & Nadal, M. (2019). A new conception of aesthetic sensitivity. *British Journal of Psychology* (Submitted).

Corradi, G., Rosselló-Mir, J., Vañó, J., Chuquichambi, E., Bertamini, M., & Munar, E. (2019). The effects of presentation time on preference for curvature of real objects and meaningless novel patterns. *British Journal of Psychology, Advance online publication*. https://doi.org/10.1111/bjop.12367.

Cotter, K. N., Silvia, P. J., Bertamini, M., Palumbo, L., & Vartanian, O. (2017). Curve appeal: Exploring individual differences in preference for curved versus angular objects. *i-Perception, 8*, 2041669517693023. https://doi.org/10.1177/2041669517693023.

Eysenck, H. J. (1940). The 'general factor' in aesthetic judgements. *Br. J. Psychol. 31*, 94–102.

Eysenck, H. J. (1981). Aesthetic preferences and individual differences. In D. O'Hare (Ed.). *Psychology and the arts* (pp. 76–101). Sussex: The Harvester Press.

Eysenck, H. J. (1983). A new measure of 'good taste' in visual art. Leonardo. *16*, 229–231.

Fechner, G. T. (1876). *Vorschule der Ästhetik.* Leipzig: Breitkopf und Härtel.

Furnham, A., & Chamorro-Premuzic, T. (2004). Personality, intelligence and, art. *Personality and Individual Differences, 36*, 705–715.

Gear, J. (1986). Eysenck's Visual Aesthetic Sensitivity Test (VAST) as an example of the need for explicitness and awareness of content in empirical aesthetics. *Poetics, 15*, 555–564.

Gómez-Puerto, G., Rosselló, J., Corradi, G., Acedo-Carmona, C., Munar, E., & Nadal, M. (2018). Preference for curved contours across cultures. *Psychology of Aesthetics, Creativity, and the Arts, 12*, 432–439.

Götz, K. O., Borisy, A. R., Lynn, R., & Eysenck, H. J. (1979). A new visual aesthetic sensitivity test: I construction and psychometric properties. *Perceptual and Motor Skills, 49*, 795–802.

Graves, M. (1948). *Design Judgement Test.* San Antonio: Psychological Corporation.

Hammond, K. R., Rohrbaugh, J., Mumpower, J., & Adelman, L. (1977). Social judgment theory: Applications in policy formation. In M. F. Kaplan, & S. Schwartz (Eds.). *Human judgment and decision processes: Applications in problem settings* (pp. 1–29). New York, NY: Academic Press.

Ho, C.-H., Lu, Y.-N., & Chen, C.-H. (2016). Influence of curvature and expertise on aesthetic preferences for mobile device designs. *International Journal of Design, 10*, 17–25.

Höfel, L., & Jacobsen, T. (2003). Temporal stability and consistency of aesthetic judgments of beauty of formal graphic patterns. *Perceptual and Motor Skills, 96*, 30–32.

Hox, J. J. (2010). *Multilevel analysis. Techniques and applications* (2nd ed.). New York: Routledge.

Jacobsen, T. (2004). Individual and group modelling of aesthetic judgment strategies. *British Journal of Psychology, 95*, 41–56.

Jacobsen, T., & Höfel, L. (2001). Aesthetics electrified: An analysis of descriptive symmetry and evaluative aesthetic judgment processes using event-related brain potentials. *Empirical Studies of the Arts, 19*, 177–190.

Jacobsen, T., & Höfel, L. (2002). Aesthetic judgments of novel graphic patterns: Analyses of individual judgments. *Perceptual and Motor Skills, 95*, 755–766.

Kampe, K. K., Frith, C. D., Dolan, R. J., & Frith, U. (2001). Reward value of attractiveness and gaze. *Nature, 413*, 589.

Leder, H., & Nadal, M. (2014). Ten years of a model of aesthetic appreciation and aesthetic judgments: The aesthetic episode—Developments and challenges in empirical aesthetics. *British Journal of Psychology, 105*, 443–464.

Leder, H., Tinio, P. P. L., Fuchs, I. M., & Bohrn, I. (2010). When attractiveness demands longer looks: The effects of situation and gender. *The Quarterly Journal of Experimental Psychology, 63*, 1858–1871.

Ma, Q., Hu, L., & Wang, X. (2015). Emotion and novelty processing in an implicit aesthetic experience of architectures: Evidence from an event-related potential study. *NeuroReport, 26*, 279–284.

Martindale, C. (2001). How does the brain compute aesthetic preference? *The General Psychologist, 36*, 25–35.

Mastandrea, S., Bartoli, G., & Bove, G. (2009). Preferences for ancient and modern art museums: Visitor experiences and personality characteristics. *Psychology of Aesthetics, Creativity, and the Arts, 3*, 164–173.

McCrae, R. R., & Costa, P. T. (2004). A contemplated revision of the NEO five-factor inventory. *Personality and Individual Differences, 36*, 587–596.

McManus, I. C., & Furnham, A. (2006). Aesthetic activities and aesthetic attitudes: Influences of education, background and personality on interest and involvement in the arts. *British Journal of Psychology, 97*, 555–587.

Meier, N. C. (1926). *Aesthetic judgment as a measure of art talent. Vol. 1.* Iowa City: University of Iowa.

Meier, N. C. (1928). A measure of art talent. *Psychological Monographs, 39*, 184–199.

Meier, N. C., & Seashore, C. E. (1929). *The Meier-Seashore art judgment test.* Iowa City: Bureau of Educational Research, University of Iowa.

Mende-Siedlecki, P., Said, C., & Todorov, A. (2012). The social evaluation of faces: A meta-analysis of functional neuroimaging studies. *Social Cognitive and Affective Neuroscience, 8*, 285–299. https://doi.org/10.1093/scan/nsr090.

Munar, E., Gómez-Puerto, G., Call, J., & Nadal, M. (2015). Common visual preference for curved contours in humans and great apes. *PLoS One, 10*, e0141106. https://doi.org/10.1371/journal.pone.0141106.

Myszkowski, N., Çelik, P., & Storme, M. (2018). A meta-analysis of the relationship between intelligence and visual "taste" measures. *Psychology of Aesthetics, Creativity, and the Arts, 12*, 24–33.

Myszkowski, N., Storme, M., Zenasni, F., & Lubart, T. (2014). Is visual aesthetic sensitivity independent from intelligence, personality and creativity? *Personality and Individual Differences, 59*, 16–20.

Nadal, M., Munar, E., Marty, G., & Cela-Conde, C. J. (2010). Visual complexity and beauty appreciation: Explaining the divergence of results. *Empirical Studies of the Arts, 28*, 173–191.

Nadal, M., Gallardo, V., & Marty, G. (2017). Commentary: Neural substrates of embodied natural beauty and social endowed beauty: An fMRI study. *Frontiers in Human Neuroscience, 11*, 596. https://doi.org/10.3389/fnhum.2017.00596.

Palumbo, L., & Bertamini, M. (2016). The curvature effect: A comparison between preference tasks. *Empirical Studies of the Arts, 34*, 35–52.

Pang, C. Y., Nadal, M., Müller, J. S., Rosenberg, R., & Klein, C. (2013). Electrophysiological correlates of looking at paintings and its association with art expertise. *Biological Psychology, 93*, 246–254.

Patrick, V. M. (2016). Everyday consumer aesthetics. *Current Opinion in Psychology, 10*, 60–64.

Pelowski, M., Markey, P. S., Lauring, J. O., & Leder, H. (2016). Visualizing the impact of art: An update and comparison of current psychological models of art experience. *Frontiers in Human Neuroscience, 10*, 160. https://doi.org/10.3389/fnhum.2016.00160.

R Core Team (2018). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Version 3.5.0. URL: https://www.R-project.org/.

Ramsoy, T. Z., & Skov, M. (2014). Brand preference affects the threshold for perceptual awareness. *Journal of Consumer Behaviour, 13*, 1–8.

Reimann, M., Zaichkowsky, J., Neuhaus, C., Bender, T., & Weber, B. (2010). Aesthetic package design: A behavioral, neural, and psychological investigation. *Journal of Consumer Psychology, 20*, 431–441.

Silvia, P. J. (2007). An introduction to multilevel modeling for research on the psychology of art and creativity. *Empirical Studies of the Arts, 25*, 1–20.

Silvia, P. J., & Barona, C. M. (2009). Do people prefer curved objects? Angularity, expertise, and aesthetic preference. *Empirical Studies of the Arts, 27*, 25–42.

Singmann, H., Bolker, B., Westfall, J., & Aust, F. (2016). *afex: Analysis of Factorial Experiments*. R package version 0.18-0. https://CRAN.R-project.org/package=afex.

Snijders, T. A. B., & Bosker, R. J. (2012). *Multilevel analysis. An introduction to basic and advanced multilevel modeling* (2nd ed.). London: SAGE Publications.

Stewart, T. R. (1988). Judgment analysis: Procedures. In B. Brehmer, & C. R. B. Joyce (Eds.). *Human judgment: The SJT view* (pp. 41–74). Amsterdam: Elsevier.

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., González-Mora, J. L., Leder, H., ... Skov, M. (2015). Architectural design and the brain: Effects of ceiling height and perceived enclosure on beauty judgments and approach-avoidance decisions. *Journal of Environmental Psychology, 41*, 10–18.

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Leder, H., Modroño, C., ... Nadal, M. (2018). Preference for curvilinear contour in interior architectural spaces: Evidence from experts and nonexperts. *Psychology of Aesthetics, Creativity, and the Arts, 13*, 110–116.

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

Wilson, A., & Chatterjee, A. (2005). The assessment of preference for balance: Introducing a new test. *Empirical Studies of the Arts, 23*, 165–180.