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Explicit and Implicit Preference for Symmetry Across Object Categories

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Abstract: Symmetry affects aesthetic judgements, and it has been extensively studied at least for faces and abstract objects. We examined the role of bilateral symmetry on aesthetic judgements across different types of stimuli. It is important to test if symmetry is equally effective in the context of objects expected to be symmetrical, e.g., faces, and objects that are almost never symmetrical, e.g., landscapes. We used the following categories: angular shapes, smooth shapes, landscapes, flowers, female faces, and male faces. We selected these image categories considering their differing degrees of curvature, familiarity to the viewer, and tendency to be perceived as ensembles, as opposed to standalone objects. We also included blobs, manipulating landscapes into blurry tessellated patterns featuring patches of color, to remove familiarity while preserving the appearance of ensembles. For each item in these categories, images were modified to obtain perfect bilateral symmetry. We collected both explicit ratings and implicit measures of symmetry preference. For landscapes, there was a clear preference for the non-symmetrical (original) version. We observed a dissociation between explicit and implicit measures. Implicit measures demonstrated positive associations for all categories.

Keywords: symmetry; preference; aesthetics; landscapes

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1. Introduction

Symmetry plays a key role in several disciplines and domains, including geometry [1], physics [2], art [3], design [4], architecture [5], computer vision [6], game theory [7], economics [8], and even, in a wider sense, social relations [9,10]. In the domain of experimental aesthetics, the fact that symmetry contributes to aesthetic judgements is well documented [11].

The present study investigates the extent to which symmetry affects aesthetic judgments across different object categories, including angular shapes, smooth shapes, landscapes, landscape-like patterns, flowers, female faces, and male faces. Specifically, we aimed to assess whether enhancing bilateral symmetry (i.e., reflection across the vertical axis) in images belonging to different contexts (i.e., geometric, natural, social), hence with different degrees of associated familiarity and prototypical symmetry, weighs differently in modulating aesthetic preference. We gauged aesthetic preference firstly from explicit ratings of symmetry salience and beauty, and secondly from performance in a task requiring speeded categorization of words and images associated either with symmetry and goodness or their opposites.

Symmetry is one of the factors that shape human preferences. It has been shown to be involved in an intricate interplay not only with intrinsic features of objects, such as complexity [12–14], order [14], and curvature [15], but also with characteristics pertaining to the relationships people entertain with the objects at hand, such as familiarity [16–18] and expertise [19,20].

Complexity, a feature that presents many aspects, can be approached by describing it in quantitative terms, with operationalizations that focus on statistical image properties involving luminance, color, spatial frequencies and other parameters, such as how much

similarity an image, as a whole, bears to each of its parts. However, different measures of objective complexity weigh in differently in the formation of subjective impressions of complexity [14]. Order is yet another perceptually salient dimension that can be separated from complexity. The balance between these two principles has been proposed as an important driving force of aesthetic appreciation [21], with individual differences affecting sensitivity to their relative proportions within stimuli [14].

One prominent aspect of order is symmetry, which is more readily grasped than other dimensions related to structure and regularity [14]. Importantly, symmetry and complexity can interact with one another in affecting preference, and participants might cluster in sets with respect to their attitudes toward the two features [12]. The presence of a symmetrical arrangement of elements in an object or scene is associated with a reduced informational load, with a consequent relieving of required perceptual and cognitive processing. This greater ease in the processing of aesthetic stimuli could in turn be associated with an enhancement of perceived beauty [22–24].

Smooth curvature is another relevant aesthetic feature [25–27]. Curvature is a visual feature that plays an essential role in guiding object categorization through the activation of a network of specialized cortical brain regions [28]. On a higher level, individual differences relating to personality traits and proficiency in the processing of aesthetic stimuli also intervene in shaping people's attitudes toward curvature [29]. For instance, people who have greater expertise in art or are more open to new experiences tend to prefer smoother curves in irregular polygons [30].

Familiarity is a factor that has long been established as exerting an influence on liking. Mere repeated exposure is sufficient to amplify affective dispositions toward an object, even in the absence of an associated reinforcement [31]. Familiarity has been found to be a modulator of appreciation for curvature versus sharpness in common-use objects. In fact, curvature is preferred when curved objects are perceived as familiar, but not when sharp objects are rated as the most familiar ones [29]. Expertise, which could be seen as a form of extreme familiarity, has been studied in relation to art. Extensive exposure to artworks has been shown to be associated with attenuated emotional responses, as measured through psychophysiological means [19]. Art expertise was also found to be associated with a mild increase in liking for asymmetry when giving explicit ratings on abstract patterns, a general preference for symmetrical patterns notwithstanding. Explicit evaluations by art experts might reflect nuanced considerations of beauty in accord with the notion of aesthetic judgments being affected by sensory, perceptual, and cognitive processes occurring across multiple levels [20,32]. The notion that symmetry is a fundamental, lifelong mediator in aesthetic experiences has also been challenged by the observation that young children show an innate attention to symmetrical patterns that dissociate from the aesthetic preferences they tend to state explicitly, suggesting that appreciation for symmetry can evolve over time [33].

Several studies have approached the study of the aesthetic experience through self-report, under the assumption that participants are able to accurately describe their preferences [34]. An alternative approach involves inference on implicit attitudes using methods such as the Implicit Association Test (IAT) paradigm. This method aims to provide indirect measurement of one's dispositions toward object categories by gauging the strength of associations between two sets of stimuli and two sets of semantic concepts with opposite emotional valence. This indirect measurement is derived from differences in response times across conditions when a categorization task is performed [35]. A study conducted by Makin et al. [36] made use of the IAT in the context of empirical aesthetics to investigate to what extent the preference for visual symmetry is an automatic response. The stimuli used included words with either positive or negative valence and various types of visual patterns, focusing particularly on reflectional symmetry compared to random, rotational, or translational patterns. Results showed an implicit preference toward symmetric dot patterns, a tendency that was mirrored in participants' explicit preferences. In another study, reflective symmetry was shown to be associated with positive valence and high arousal [37].

Differences in aesthetic preferences toward the same categories can be detected depending on whether the explicit or implicit approach is adopted. For instance, studies on the role of expertise in the aesthetic experience have shown how the explicit preferences of experts in design [38] and art [20] do not always align with their implicit preferences, revealing that overt and latent aesthetic attitudes can show dissociations. Another more recent study employing the IAT found that an implicit preference detected for golden ratio dot patterns compared with random patterns did not correlate with explicit preference [39].

With the present study, we sought to replicate the finding that symmetry affects aesthetic judgements differentially based on object categorization and familiarity to prototypical object representations [40], collecting both explicit and implicit measures of symmetry preference across a range of object categories in two experiments.

In the first experiment, participants were asked to give both beauty and symmetry ratings using a visual analogue scale. Each viewer was exposed to only the veridical or symmetrical version of a given item. Items belonged to six categories (angular shapes, smooth shapes, landscapes, flowers, female faces, and male faces) used by Bertamini et al. [40] and a novel category of landscape-like patterns called "blobs" that were introduced for the purposes of the present study. Blobs were crafted by obfuscating the individual features of the elements that make up landscape images (e.g., trees, clouds) to reduce their familiarity to the viewer while retaining their pattern-like quality. Here, we intend familiarity not as the result of repeated exposure, but as the extent to which a stimulus is perceived as ecologically plausible. In this sense, in the context of our study, the concept of familiarity overlaps with "naturalness" and "ecological validity", as abstracted from prototypical representations of landscapes. In the second experiment, participants engaged in an Implicit Association Test focused on images of landscapes, blobs, and angular shapes. A subset of subjects participated in both experiments, enabling a comparison between measures of explicit and implicit preference for symmetry.

First, we questioned a common and strong view that symmetry is always a factor that will determine preference. This effect must be placed in the context in which symmetry is presented and whether we are referring to explicit or implicit preferences. For explicit judgments, there are already a few cases where people do not express a preference for symmetry, for example, when people's preferences are influenced by expertise [20,41]. Moreover, specific types of symmetry may also be preferred to others depending on the type of stimulus. For instance, radial symmetry in flowers has been found to be preferred to bilateral symmetry, possibly because of its association with the prototypical arrangement of petals in flowers [42]. Here, we only investigated bilateral symmetry. Based on the work by Bertamini et al. [40], we expected the following: a preference for more symmetric abstract shapes and faces over veridical ones; no preference for more symmetric flowers over veridical ones; a preference for veridical landscapes, which may appear more prototypical, since natural scenes rarely display a high degree of symmetry in ecological settings or non-manipulated pictures. In line with this, since blobs featured a landscape-like layout but reduced familiarity (in the sense of ecological validity), we expected that the symmetrical versions of these stimuli would be judged more favorably compared with landscapes. Second, based on previous findings [20,36,43], we expected to find a generalized implicit preference for symmetry, with possible dissociations from explicit preference in select object categories, most notably landscapes.

2. Experiment 1

2.1. Method

2.1.1. Participants

A total of 100 participants aged 20 to 45 (69 female, Mage = 23, SDage = 3.57) took part in Experiment 1. Participants were recruited from students at the University of Padova. No exclusion criteria were applied and no monetary compensation was given. This study was conducted in accordance with the principles of the Declaration of Helsinki, with prior approval from the Ethics Committee of the Department of General Psychology at the

University of Padova (Protocol number: 4783). All participants provided their consent through an online form. The experimental procedure was implemented using JavaScript's library jsPsych [44] to display the stimuli on the participant's laptop or tablet via a browser (e.g., Google Chrome). This allowed simultaneous online data collection on a large sample of students, each using their own personal device. Both Experiment 1 and Experiment 2 (see below) were conducted in a classroom setting under the supervision of the experimenter, as part of a course in psychology, aesthetics, and art.

2.1.2. Materials

Seven sets of ten pairs of images were used. Within each set, 10 images displayed partial intrinsic symmetry but lacked perfect bilateral symmetry across the vertical axis, whereas the other 10 images were manipulated to display perfect vertical symmetry. Six of the seven sets of images were the same as those used by Bertamini et al. [40]: angular shapes, smooth shapes, landscapes, flowers, female faces, and male faces (Figure 1).

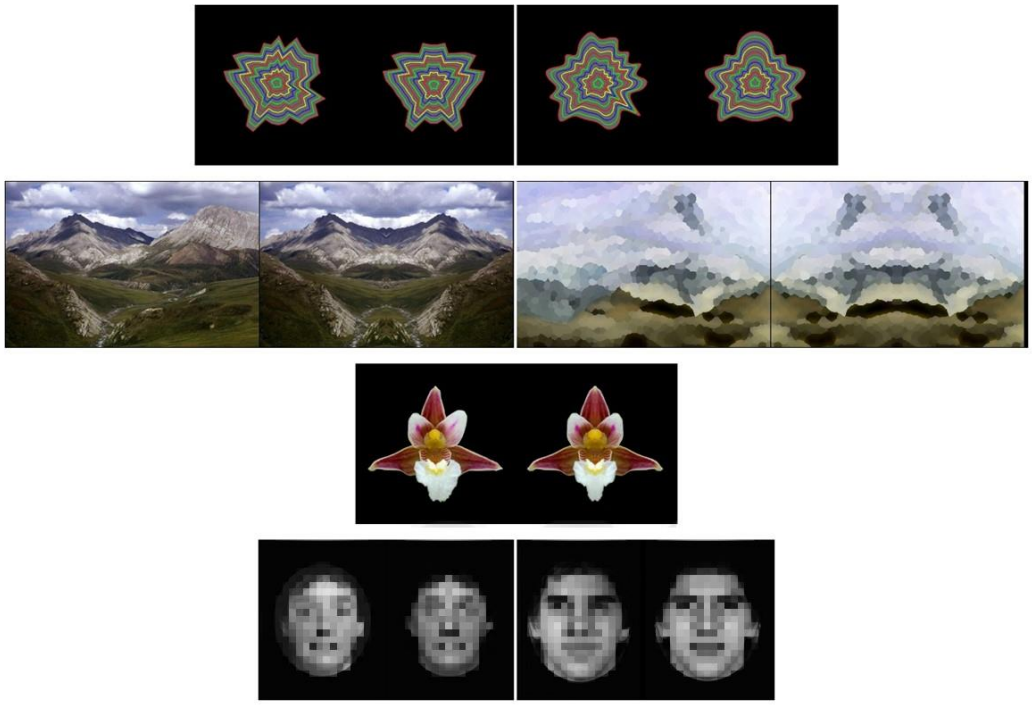

Figure 1. From left to right and top to bottom, exemplars of angular shapes, smooth shapes, landscapes, blobs, flowers, female faces, and male faces. The veridical version is on the left side and the symmetrical version on the right side. For privacy reasons, the faces displayed in the figure are mosaic versions of the original face stimuli viewed by participants during the experiment. For the original images, see Rhodes et al. [45].

Angular shapes were built by creating irregular polygons with 36 vertices, of which 16 were concave and 20 were convex. Smooth shapes were derived from angular shapes by smoothing their edges with a cubic spline.

Landscape stimuli consisted of images downloaded from the internet using the word "landscape" as a search keyword. These images displayed a variety of outdoor scenes. For each image, a bilaterally symmetrical version was produced.

Flower stimuli were obtained from a study by Hůla and Flegr [42]. A subset of flower species was selected, and each image was subjected to manipulation that yielded its bilaterally symmetrical version.

Face stimuli belonged to a set of black and white photographs of young human subjects employed in a study by Rhodes et al. [45] on symmetry preference. These images

could depict either male or female faces (10 male and 10 female). The veridical images and the ones with perfect bilateral symmetry came from the original study.

One additional category, "blobs", was created by manipulating landscape images through GIMP photo-editing software, version 2.10.24, to craft them into coarse-grained honeycomb-like textures of polygons with pixelated edges, reminiscent of Voronoi cells. These stimuli provided roughly blurred variants of each image in the landscape category, comprising both veridical and symmetrical ones. The purpose of this addition was to introduce a novel image category characterized by the absence of familiarity, while preserving a pattern-like quality simulating the heterogeneous character of natural landscapes.

The original versions of the images from which these symmetrical counterparts were derived are referred to as "veridical". All images were presented on a uniform background. Image height was set to 400 pixels and the original aspect ratio was maintained, with landscapes and blobs retaining higher width compared with other image categories. No participants reported any issues with the size or resolution of the images.

2.1.3. Procedure

Participants completed two blocks of trials in a fixed order. In the first block, the task was to rate the beauty of each image. In the second block, the task was to rate the salience of symmetry in each image, meaning the ease and fluency with which overall symmetry was perceived by the observer. In both blocks, participants were required to provide a judgement on each of 70 images—10 per image category—presented sequentially and in random order in the center of their screen. At every trial, participants would drag a cursor along a slider placed below the image, which provided a visual analogue scale. The placement of the cursor would be registered as a number in a range from 1, representing a complete lack of beauty (first block) or symmetry (second block), to 100, representing maximal beauty or symmetry, with a resolution of 1 unit. The images presented to each participant across the two blocks were the same, but in a different order. Each block was preceded by a short training of 7 mock trials in which the stimuli were exemplified by the words identifying the image categories (e.g., "female face"), so that participants could familiarize themselves with the slider before engaging in the actual task. Two variants of the experiment were prepared, counterbalanced so that each participant would only see either the veridical or symmetrical version of a given item, but never both. Within each of the two blocks, participants assigned to one variant would view 5 veridical and 5 symmetrical images belonging to a given category, whereas participants assigned to the other would view the corresponding symmetrical and veridical versions of those items. No constraints were put on viewing time for each stimulus.

2.1.4. Scoring

The analyses were performed in R Studio using R version 4.3.0 [46]. In this experiment, the dependent measures were the scores representing the participants' subjective ratings about beauty and symmetry salience in the images they were presented with. Both sets of scores (i.e., beauty, salience) were standardized by subtracting the mean of each individual participant's ratings from their scores and then dividing by the standard deviation. This standardization was applied using the mean and standard deviation calculated separately for each participant, not for the entire sample.

2.2. Results

Since each participant could only see either the veridical or symmetrical version of each item within a given category, independent *t*-tests were conducted to compare mean beauty ratings between symmetrical and veridical stimuli within object categories, performing a total of 7 comparisons. The *p*-values were adjusted for multiple comparisons using the False Discovery Rate (FDR) correction method by Benjamani–Hochberg [47]. The results, including both the original and FDR-corrected *p*-values, are presented in Table 1.

Table 1. Results of *t*-tests on beauty ratings comparing symmetrical and veridical image versions across categories.

Category	t-Statistic	Mean Diff.	Direction	*p* Value	Corrected *p* Value
Angular	3.424	0.147	Sym > Ver	<0.001	0.002
Smooth	3.283	0.151	Sym > Ver	0.001	0.002
Landscape	−12.65	−0.584	Ver > Sym	<0.001	<0.001
Blob	−3.06	−0.178	Ver > Sym	0.002	0.004
Flower	−0.592	−0.028	Ver > Sym	0.554	0.647
Female	−0.318	−0.016	Ver > Sym	0.751	0.751
Male	−2.004	−0.101	Ver > Sym	0.045	0.064

For angular shapes, there was a significant preference for symmetrical images over veridical ones, with a mean difference of 0.147, t(993.511) = 3.424, FDR-corrected $p = 0.002$. Similarly, for smooth shapes, the mean difference was 0.151, indicating a positive response to symmetry, t(997.637) = 3.283, FDR-corrected $p = 0.002$. In contrast, for landscapes and blobs, there was a significant preference for veridical images. The largest difference was observed for landscapes, with a mean difference of −0.584, t(933.686) = −12.65, FDR-corrected $p < 0.001$. For blobs, the mean difference was −0.178, t(997.077) = −3.06, FDR-corrected $p = 0.004$. No significant preference relative to symmetry was detected in the flower category, with a mean difference of −0.028, t(997.755) = −0.592, FDR-corrected $p = 0.647$. In the face category, no significant preference was detected for either female faces, mean difference = −0.016, t(997.749) = −0.318, FDR-corrected $p = 0.751$, or male faces, mean difference = −0.101, t(997.895) = −2.004, FDR-corrected $p = 0.064$. The pattern of preference across veridical and symmetrical versions of items in each object category is visualized in Figure 2.

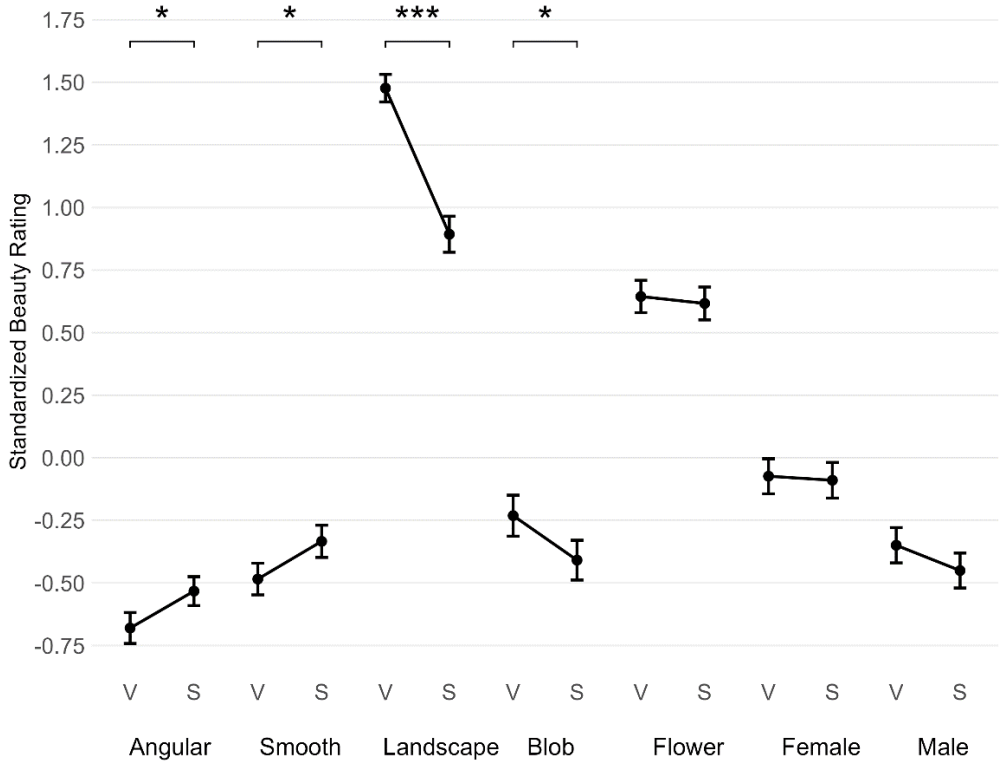

Figure 2. Standardized beauty ratings across seven object categories are shown. Each category is divided into veridical (V) and symmetrical (S) conditions. Error bars represent the 95% confidence intervals of the mean standardized beauty ratings. Significant differences between conditions within each category are indicated by asterisks, where * $p < 0.05$ and *** $p < 0.001$.

To confirm that the experimental manipulation of symmetry was successful, independent *t*-tests were also conducted performing comparisons across symmetrical and veridical images on symmetry salience ratings within the same 7 object categories. The obtained *p*-values were adjusted using FDR correction. Results on salience ratings confirm that the manipulation performed by introducing perfect bilateral symmetry yielded the desired perceptual outcome: for all categories, symmetrical images were rated as having significantly more salient symmetry than their veridical counterparts. Landscapes showed the largest difference, with a mean difference of 2.006, t(761.314) = 53.892, FDR-corrected $p < 0.001$. Flowers showed the smallest difference, with a mean difference of 0.965, t(756.742) = 26.960, FDR-corrected $p < 0.001$. All remaining categories also showed significant differences in salience ratings between symmetrical and veridical images, with FDR-corrected $p < 0.001$ for angular (mean difference = 1.884, t(992.401) = 56.600), smooth (mean difference = 1.857, t(976.367) = 57.600), blob (mean difference = 1.792, t(989.529) = 52.164), female (mean difference = 1.218, t(961.614) = 35.656), and male (mean difference = 1.277, t(992.466) = 39.968) categories. The results, including both the original and FDR-corrected *p*-values, are presented in Table 2.

Table 2. Results of *t*-tests on symmetry salience ratings comparing symmetrical and veridical image versions across categories.

Category	t-Statistic	Mean Diff.	Direction	*p* Value	Corrected *p* Value
Angular	56.6	1.884	Sym > Ver	<0.001	<0.001
Smooth	57.6	1.857	Sym > Ver	<0.001	<0.001
Landscape	53.892	2.006	Sym > Ver	<0.001	<0.001
Blob	52.164	1.792	Sym > Ver	<0.001	<0.001
Flower	26.96	0.965	Sym > Ver	<0.001	<0.001
Female	35.656	1.218	Sym > Ver	<0.001	<0.001
Male	39.968	1.277	Sym > Ver	<0.001	<0.001

Additionally, to assess the relationship between salience and beauty ratings across object categories, Spearman correlations were computed. These were performed jointly for ratings given to symmetrical and veridical images, with 7 correlations for each set of ratings, adjusting for multiple comparisons using the FDR method. Across categories, considering all items regardless of image version, significant (FDR-corrected $p < 0.05$) but weak correlations were observed for several categories. Angular shapes exhibited a weakly positive correlation between salience and beauty ratings, rs = 0.148, FDR-corrected $p < 0.001$. Smooth shapes also showed a weakly positive correlation, rs = 0.141, FDR-corrected $p < 0.001$. In contrast, landscapes displayed a weakly negative correlation, rs = −0.293, FDR-corrected $p < 0.001$. Flowers showed a significant but negligible correlation, rs = 0.085, FDR-corrected $p = 0.013$. However, blobs, female faces, and male faces did not show significant correlations, with rs = −0.01 for blobs, rs = 0.056 for female faces, and rs = 0.056 for male faces, with FDR-corrected *p* values of 0.747, 0.092, and 0.092, respectively. Results, including both the original and FDR-corrected *p*-values, are shown in Table 3.

To determine whether the role of symmetry salience on beauty ratings varied between image versions within each category, we constructed a generalized linear mixed model (GLMM) for each category. Symmetry salience, image version, and their interaction were used as predictors of beauty ratings, with subject and item included as random effects. For landscapes, the model did not indicate a significant relationship between salience and beauty ratings ($\beta = -0.04397$, SE = 0.04226, $p = 0.29839$) for veridical images. However, the significant positive interaction term ($\beta = 0.27299$, SE = 0.08907, $p = 0.00224$) revealed a positive relationship between salience and beauty for symmetrical landscapes compared with veridical ones. For the remaining categories, we did not detect any significant effects of salience rating, image version, or their interactions on beauty ratings. Predictions extracted from the individual category models are visualized in Figure 3. An additional analysis

examining the effect of gender on beauty ratings was conducted and is included in the Supplementary Materials, which are available at https://osf.io/mqb64/.

Table 3. Results of Spearman correlations between symmetry salience and beauty ratings across categories.

Category	Spearman Correlation	*p* Value	Corrected *p* Value
Angular	0.148	<0.001	<0.001
Smooth	0.141	<0.001	<0.001
Landscape	−0.293	<0.001	<0.001
Blob	−0.01	0.747	0.747
Flower	0.085	0.007	0.013
Female	0.056	0.079	0.092
Male	0.056	0.076	0.092

2.3. Discussion

Regarding beauty ratings, results hint at the appeal of enhanced bilateral symmetry in an image being dependent on the nature of the image itself. The overall pattern of results reveals how symmetry tends to be preferred in man-made renderings of abstract shapes, whereas authenticity is instead preferred in objects drawn from the natural world. Specifically, a significant preference for symmetrical images over veridical ones emerged in the categories of angular and smooth shapes, while the opposite was observed for the categories of landscapes and blobs. For flowers and faces, both female and male, no significant preference for either symmetrical or veridical versions was detected, perhaps due to their high intrinsic symmetry curbing the effect of our manipulation of bilateral symmetry. It is also to be mentioned that faces were the only category whose images were displayed in grayscale, faithfully to the original stimuli employed by Rhodes et al. [45].

Alongside beauty ratings, symmetry salience ratings were collected as a subjective measure of the ease with which overall symmetry was perceived in the images. These reports of the immediate impressions of symmetry conveyed by the stimuli were used as a proxy for perceptual fluency (see Reber et al. [22]). We expected symmetry salience to display a moderate degree of variability among participants despite our manipulation of bilateral symmetry. In line with the previous results [40], we found that landscapes represent both the category in which symmetry is most salient and the one with the largest mean difference in beauty ratings between symmetrical and veridical images, in the direction of a preference for veridical landscapes. Interestingly, a closer examination revealed that symmetry can still enhance beauty even in categories where veridical versions are preferred. We found higher symmetry salience to be associated with higher beauty ratings within symmetrical landscape images, even though these were generally disliked compared with veridical ones. This indicates a complex interplay between symmetry and other aesthetic qualities that transcend low-level sensory and perceptual properties, such as naturalness and authenticity.

While for categories like angular and smooth shapes a preference for regularity seems justified by their artificial nature, in categories of objects of natural origin, such as flowers and faces, the preference patterns are less straightforward. Again, these findings seem to imply that while symmetry is an important aesthetic factor, its impact on preference can be elusive. In fact, symmetry can interact not only with low-level sensory and perceptual object features, such as color and complexity, but also with higher-level factors such as familiarity, which vary across categories. In other words, our results support the notion that symmetry enhances beauty in a context-dependent rather than a generalized manner. This emphasizes the importance of considering both intrinsic symmetry and the context in which images are perceived when evaluating aesthetic preferences, as exemplified by the nuanced relationship between symmetry salience and perceived beauty described for responses to landscape images.

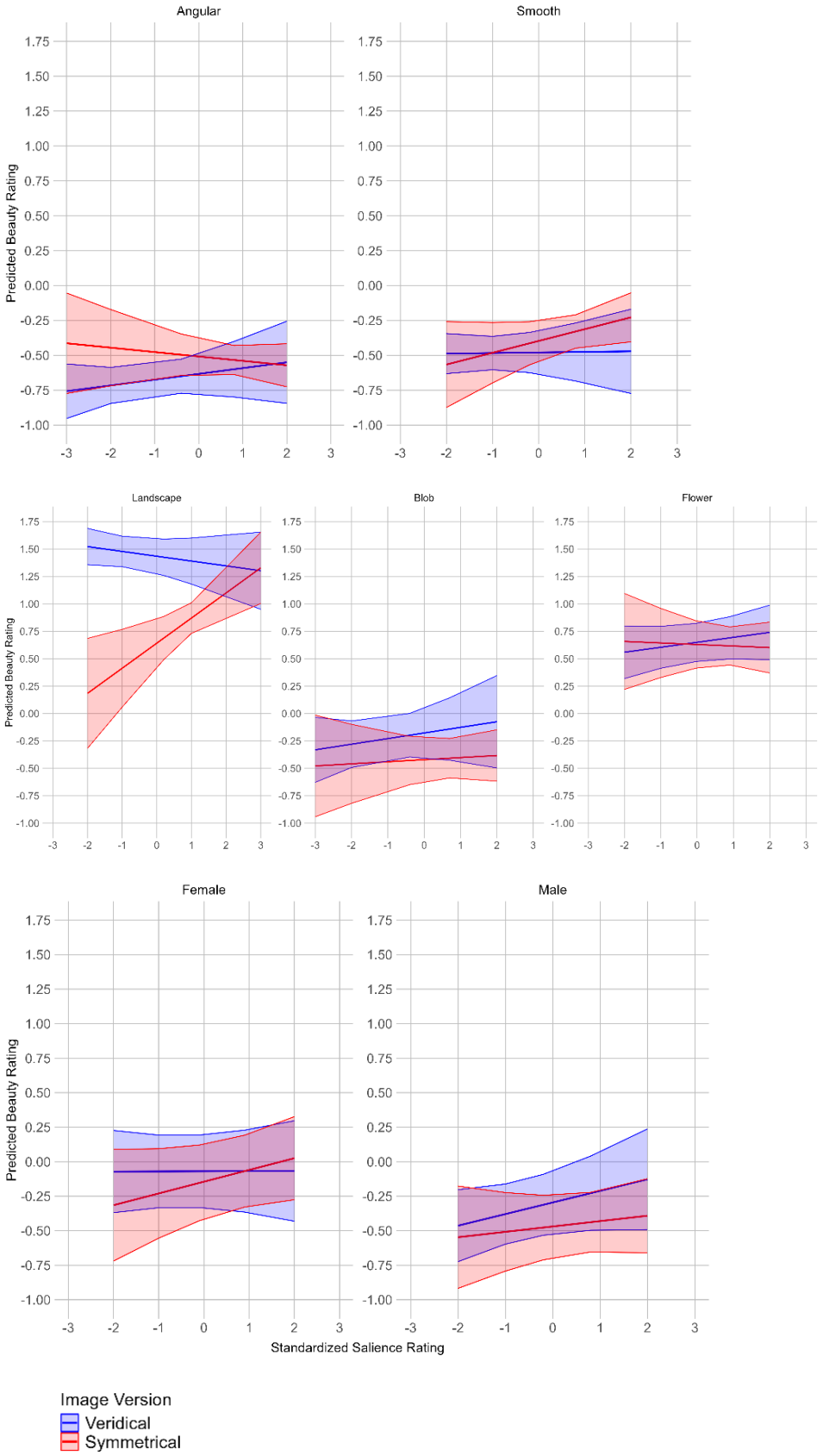

Figure 3. The blue lines represent the predictions for veridical stimuli, while the red lines represent the predictions for symmetrical stimuli. Ribbons around the lines indicate the 95% confidence intervals. The x−axis represents the standardized symmetry salience rating and the y−axis represents the predicted beauty rating.

3. Experiment 2

3.1. Method

3.1.1. Participants

A total of 49 participants (37 female, aged 20–31, Mage = 22.9, SDage = 2.66) were recruited through the same means of the previous experiment, which was completed by 42 of these participants (32 female, aged 20–31, Mage = 22.9, SDage = 2.77).

3.1.2. Materials

From the seven image categories used in the previous experiment, we selected three from those in which significant differences in beauty ratings based on symmetry were detected: landscapes, blobs, and angular shapes. The stimuli also included two sets of words, 10 with positive valence (freedom, friend, heaven, honor, loyal, lucky, kiss, paradise, pleasure, rainbow) and 10 with negative valence (accident, cancer, death, disaster, evil, filth, hatred, poison, sickness, torture). These words were selected from the Affective Norms for English Words (ANEW) database [48] and correspond to those used in an IAT study by Makin et al. [36].

3.1.3. Procedure

Participants engaged in IAT procedure adapted from a study by Makin et al. [36], which in turn was based on the guidelines proposed by Nosek et al. [49]. Responses were given through each device's keyboard, by pressing the keys "E" and "I", from now on referred to as the left button and right button, respectively. Participants completed eight blocks of trials. The first two blocks (training) consisted of 20 trials each and were performed as follows: in the first training block, the task was to press the left button when presented with symmetrical images and the right button when presented with veridical images; in the second training block, the task was to press the left button when presented with positive words and the right button when presented with negative words. In the following two 40-trial blocks (experimental), each trial's stimulus was either an image or a word to be sorted in accord with on-screen verbal cues. These blocks were compatible, meaning that symmetrical images and positive words were responded to using the same button (left), whereas veridical images and negative words were responded to using the right button (right). The next two blocks were training blocks of 20 trials each, in which only images were presented, and the response mapping was reversed (i.e., left button for veridical images and right button for symmetrical images) in order to let participants update the learned association rules. Lastly, there were two incompatible experimental blocks of 40 trials each, in which the left button was mapped to veridical images or positive words, and the right button was mapped to symmetrical images or negative words. One half of the participants performed the task as described, while the other half performed the incompatible blocks first and the compatible blocks second, with training blocks rearranged in accordance with this order. Participants could read written instructions on the screen before the start of each block, informing them about the incoming block's response mapping. In all trials, cue words appeared above the stimuli simultaneously with their presentation and positioned to the left or to the right based on the response mapping. The cues "symmetry" and "random" would appear during the presentation of images, while the cues "positive" and "negative" would appear during the presentation of words. Participants had no time limit to provide a response but were instructed to respond as fast and accurately as possible. In the case of a wrong response, a red "X" superimposed on the stimulus signaled the error, prompting participants to give the correct response necessary to move on to the next trial. Consecutive trials were separated by a 200 ms gap. Each eight-block procedure was repeated three times, one for each of the following image categories: landscapes, blobs, and angular shapes. The order in which categories were displayed was the same across all participants.

3.1.4. Scoring

Data were processed using a simplified algorithm adapted from the general guidelines proposed for IAT analysis [49], as follows. Firstly, data were filtered to exclude training

trials and trials with reaction times (RTs) exceeding 10,000 ms, and it was verified that no subject performed more than 10% of trials with RTs smaller than 300 ms. Then, for each combination of block, category, and item, the mean reaction time for correct trials was calculated across participants, replacing each RT in incorrect trials with this value plus a 600 ms penalty. After these pre-processing steps, for each participant, the mean and standard deviation of RTs were calculated for both compatible and incompatible trials, grouped by category. Next, we computed the pooled standard deviation, which combined the variability of compatible and incompatible trials. Finally, the D-score for each subject and image type was calculated as the difference between the mean reaction times for incompatible and compatible trials, divided by the pooled standard deviation. A positive D-score thus indicated that compatible trials were met with faster responses, reflecting an implicit positive bias toward symmetry.

3.2. Results

Analyses were performed in RStudio using R Version 4.3.0 [46]. To determine whether participants achieved positive D-scores across the three object categories (i.e., angular images, blobs, and landscapes), one-sample *t*-tests were conducted. These tests compared the D-scores of each object category against zero. The results confirmed that the D-scores were significantly different from zero ($p < 0.001$) for all three object categories, indicating a significant positive bias toward symmetry. The t-statistics and corresponding *p*-values for each category are summarized in Table 4.

Table 4. Results of *t*-tests on D-scores for angular shapes, blobs, and landscapes.

Category	t-Statistic	*p* Value	CI Low	CI High
Angular	6.592	<0.001	0.164	0.307
Blob	6.166	<0.001	0.145	0.285
Landscape	3.707	<0.001	0.094	0.317

An ANOVA was used to test the differences in D-scores between the three categories. Results showed no significant differences, suggesting that the positive implicit bias toward symmetry was consistent regardless of category ($F(2, 144) = 0.126$, $p = 0.881$). In Figure 4, the individual D-score values across different categories are represented, showing the overall tendency for faster responses in trials in which symmetry shared the response mapping with positive valence words (i.e., compatible trials).

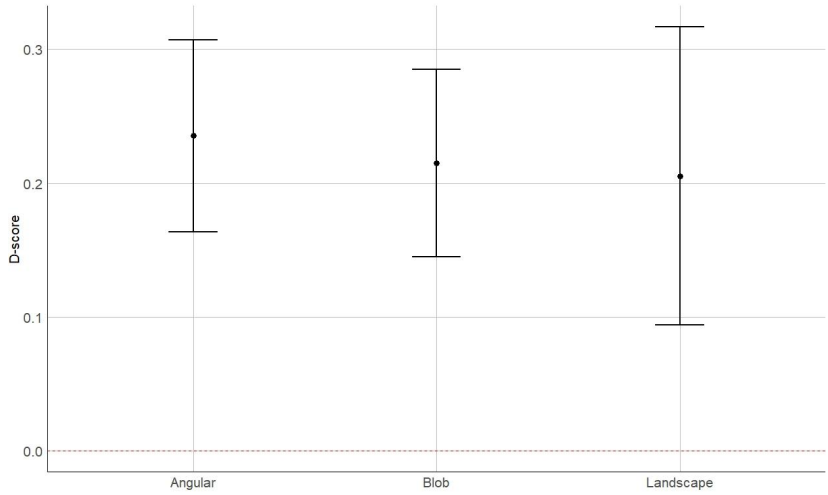

Figure 4. D-scores by object category. Each point represents the mean D-score, with bars representing 95% confidence intervals. The dashed red line marks a D-score of zero as a reference point.

3.3. Discussion

The finding that implicit attitudes toward symmetry, as indirectly measured through the IAT, are indiscriminately positive across the three object categories of angular shapes, blobs, and landscapes highlights a dissociation with the patterns emerging from explicit ratings. While the implicit measures reveal a consistent positive bias toward symmetry, explicit ratings of beauty display a more nuanced picture in which symmetry is not always appreciated, as some stimuli are preferred in their original version. Notably, this dissociation is compatible with the findings of previous studies showing how explicit preferences, influenced by factors such as expertise, often do not match the profile of covert attitudes inferred from tasks like the IAT, which are designed to bypass conscious expression of likes and dislikes [20,38].

4. General Discussion

In this study, we investigated the role of bilateral symmetry in the formation of aesthetic judgements on exemplars of widely different object categories. We hypothesized that artificial enhancement of bilateral symmetry in the images used as stimuli would affect preference with varying degrees of strength depending on object category. It also needs to be highlighted that the selected categories differed not only for their mere semantic value, but also along a dimension of familiarity to the viewer, and for the amount and types of non-bilateral symmetries displayed (e.g., radial symmetry). In our first experiment, using a visual analogue scale, we collected explicit beauty ratings for images belonging to seven categories: angular shapes, smooth shapes, flowers, landscapes, blobs, female faces, and male faces. Each viewer was exposed to either the veridical (i.e., original) or symmetrical version of a given image, and the successful manipulation of symmetry was confirmed through the analysis of symmetry salience ratings across the original and the manipulated images. In our second experiment, we used an IAT paradigm to analyze reaction times in the speeded binary categorization of words and images, aiming to infer the magnitude of implicit liking toward three select object categories: landscapes, blobs, and angular shapes.

When considering explicit aesthetic judgements of beauty, results are indicative of a general pattern of differential preference for symmetry across object categories found by Bertamini et al. [40]: symmetry affects the formation of aesthetic preference more strongly when viewing stimuli belonging to specific contexts compared with others, and not always in the same direction. Importantly, more symmetry does not always imply an increase in liking: in the case of landscapes, an increase in symmetry is associated with a decrease in beauty ratings, most likely because order is perceived as an unnatural occurrence in outdoor scenes that are devoid of human-made elements, as for our landscape stimuli. In fact, familiarity and the tendency to perceive specific classes of stimuli holistically or as a composite seem to be particularly important in modulating aesthetic attitudes toward exemplars of different categories. Furthermore, since objects such as flowers and human faces inherently display symmetry, albeit of different types and to a different extent based on natural variability, the artificial enhancement of bilateral symmetry is bound to affect symmetry salience with different levels of conspicuousness.

We found a dissociation between explicit and implicit preferences for symmetrical objects. While preference for symmetric angular shapes was evident both from explicit and implicit measures of symmetry preference, this was not the case for landscapes and blobs. While from explicit ratings it emerged that landscapes and blobs were disliked in their symmetrical versions compared with the veridical ones, positive D-scores were registered in both categories, suggesting category-agnostic implicit attitudes toward symmetry. This highlights a nuanced relationship between estimated covert biases and overt responses in relation to symmetry across image categories encompassing geometrical, natural, and socially salient stimuli. It is to be noted that the object categories chosen for our study are typically marked by rich sets of features and several peculiarities that are known to affect aesthetic judgements in context-dependent ways, some of which are summarized below.

In abstract shapes, preference for smooth curved contours seems to be not only stable across different kinds of tasks, involving both forced-choice with limited presentation time and explicit ratings, but also strongest when intermediate complexity is achieved by balancing vertices and concavities [50]. However, studies that investigated preference for curved objects differ by other factors that are particular to the paradigms used, such as for how long the objects to be rated are visible and whether the task at hand involves semantic association or other cognitive processes [27]. Relating to this last point, another factor that might modulate the general preference for curvature could be the presence of affordances associated with the objects that are being perceived, which is to say the options for the physical interaction they offer in real or simulated ecological settings, as opposed to the detached evaluative mode they call for when represented in two-dimensional pictures [51]. Our results show that abstract stimuli, in the form of two-dimensional shapes featuring either smooth (i.e., curved) or angular closed contours, were perceived similarly regardless of this manipulation, with symmetrical versions being preferred.

Landscapes are objects that typically display high complexity, as they are ensembles of elements that can be of both natural and anthropic origin. From an evolutionary standpoint, it makes sense for humans to prefer landscapes that are readily explorable and offer shelter, thus fostering survival. Beyond these biologically driven predispositions, it is possible to individuate personal and cultural factors that contribute to determining attitudes toward landscapes. A framework of general principles driving the aesthetic character of landscapes has been proposed by Tveit et al. [52] (see also Ode et al. [53]), who proposed that important dimensions in landscape aesthetics include complexity, defined as the "diversity and richness of landscape elements and features, their interspersion as well as the grain size of the landscape", and naturalness, which relates to how close a landscape is to a pristine state untouched by artificial interventions. It has been argued that because of the intrinsic heterogeneity of outdoor environments, they are not likely to be processed in a holistic fashion, as instead happens with faces, but are rather treated as composites that are unlikely to display a high degree of symmetry or order, unless deliberately affected in such a direction by human activities like vegetation management or the construction of buildings. In other words, most landscapes lack "objectness" (i.e., the evoked perception of an object as bounded, cohesive, and self-standing) [40]. Familiarity with prototypical natural landscapes is thus likely to exert a strong influence on how people react to landscape images that feature an orderly disposition of elements, and specifically a bilaterally symmetrical one, as the routinary experience of exemplars drawn from this category is that of collections of distinct elements that are almost never arranged in orderly structures and are thus not readily perceived as unitary [40]. This could at least partially explain our finding that symmetrical blobs, as landscape analogues designed to reduce familiarity, are met with less dislike than symmetrical landscapes. Compositional techniques play a key role in crafting aesthetically pleasing images, especially in landscape photography [54]. For instance, the rule-of-thirds represents a well-known principle that enhances visual interest by placing key elements on a grid dividing the image into thirds along the vertical and horizontal axes [55,56]. The rule of thirds and golden section proportions are often exploited to achieve optimal horizon placement [56]. However, strict adherence to such rules is not always indicative of the aesthetic value of pictures [57,58]. It has been suggested that exceedingly orderly features, such as perfect symmetry, may reduce interest, whereas intentional asymmetry may add dynamism and engagement [59,60].

Flowers are natural objects that can be characterized by different kinds of symmetry, the most common of which are radial and bilateral symmetry. Symmetrical features in flower morphology can be at least partially explained by examining the relationships flowers entertain with pollinator animals [61]. Along with other cues such as color, a symmetrical appearance can steer the foraging behavior of bumblebees toward the selection of specific flowers. Likewise, certain aesthetic characteristics in flowers can be particularly attractive to humans. In a study conducted by Hůla and Flegr [42], participants evaluated the attractiveness of 52 common wildflowers. Flowers that exhibited radial

symmetry and were less complex were judged by observers as the most beautiful, possibly because they are more prototypical. Interestingly, our results did not show an effect of added bilateral symmetry in driving aesthetic preference for flower images that were a manipulated subset of those employed by Hůla and Flegr [42]. Different types of symmetry may affect preference in different ways based on their level of salience in prototypical object representations.

Faces constitute yet another class of complex aesthetic stimuli for several reasons, including their social relevance as evolutionarily salient objects [62]. While there is evidence that different cultures share a general agreement as to which faces appear attractive [63], recent studies have highlighted how cultural idiosyncrasies play a role in shaping facial attractiveness [64]. The perceived characteristics of a face, such as subjective attractiveness, relate to the interaction of several factors that include, on one hand, dimensions pertaining to the observer, such as their preferences for specific sets of features [65], their self-rated attractiveness [66], and their ethnicity and gender [67], and on the other, physical characteristics that can be described quantitatively, for instance the relative distance of facial landmarks [68]. Along with features such as averageness, prototypicality, and the strength of sexually dimorphic traits, the degree of symmetry that a face displays is an important factor in determining attractiveness [69]. However, it is quite challenging to disentangle the relative role of these factors in making a face appear beautiful. For instance, symmetry could add to facial beauty at least partially through an enhancement of its normality [70]. Face expertise is yet another factor that influences the formation of facial beauty judgments, as it happens with other kinds of aesthetic stimuli [71]. Overall, we did not find that a boost in bilateral symmetry would enhance the appeal of either female or male faces, failing to replicate the finding of Rhodes et al. [45].

Limitations of the present study include a lack of control for low-level features of the images that were shown as stimuli, most notably color. While face stimuli were displayed in grayscale, as in the original study by Rhodes et al. [45], all other items featured color. While abstract shapes displayed a limited set of colors, blobs and natural images intrinsically displayed a wide range of colors. Spatial frequency content was also not controlled for, as the images belonged to categories with widely different form features. Although at the time of data collection participants performed the experiments as part of a course on aesthetics and art, individual aesthetic backgrounds were not assessed. Future studies might investigate whether symmetry appreciation across image categories is modulated by factors such as familiarity with the categories of interest, individual aesthetic expertise resulting from formal education or training, and culture of origin.

In summary, our findings highlight how the multifaceted role of symmetry in driving aesthetic preference still needs to be explored, with particular attention to contextual factors that could possibly mediate this process, most notably the object category to which the perceived stimuli belong. In fact, different types of objects can vary significantly along dimensions that can display complex interactions with symmetry, such as "objectness", complexity, and familiarity. Specifically, we observed how it is possible to detect implicit appreciation for heightened symmetry even within object categories that people generally rate as more beautiful in their veridical versions, such as landscapes, replicating the findings of Bertamini et al. [40]. Moreover, this aligns with our observation that it is possible to detect dissociations between explicit preferences for symmetry, reported through rating scales in self-report tasks, and implicit preferences, inferred using tools that estimate how strongly one associates symmetry with positive semantic concepts. From explicit ratings, it emerged that symmetric angular shapes and veridical landscapes were preferred over their respective counterparts, while symmetry was found to be covertly preferred to randomness in both categories, as gleaned from implicit measures. In parallel to this dissociation, a higher salience of symmetry, whether intrinsic or artificially enhanced, was not always met with favorable beauty ratings across all categories. The overall pleasantness of an object results from the simultaneous weighing of many variables that jointly affect our aesthetic experiences. This poses a challenge to accurate measurements of aesthetic preference in

reliable and ecologically sound ways [72]. Despite methodological limitations related to this issue, several studies have identified general relationships between several systematically manipulated features, including symmetry, and people's tendency to express an aesthetic preference toward stimuli in which these are salient [73]. To conclude, our findings align with previous evidence of dissociation between implicit and explicit aesthetic attitudes in the framework of a differential role of symmetry across object categories, supporting a dual approach aimed at exploiting both implicit and explicit measures in the investigation of the role of symmetry in aesthetic preference.

Supplementary Materials: The following supporting information can be downloaded at: https://osf.io/mqb64/.

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