

Preference for Curvilinear Contour in Interior Architectural Spaces: Evidence From Experts and Nonexperts

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Much evidence suggests that preference for curvilinear visual contour is robust. We collected data from experts (i.e., self-identified architects and designers) and nonexperts to test the hypothesis that expertise moderates one's sensitivity to curvilinear contour within architectural spaces. When assessing beauty, experts found rectilinear spaces less beautiful than curvilinear spaces, whereas contour had no effect on beauty judgments among nonexperts. In contrast, when making approach-avoidance decisions, nonexperts were more likely to opt to enter curvilinear than rectilinear spaces, whereas contour had no effect on approach-avoidance decisions among experts. These results bolster the case for the importance of contour as an important and potentially adaptive feature in architecture and design, but stress the impact of expertise on its aesthetic and motivational relevance.

Keywords: architecture, design, contour, angularity, expertise

Scientific interest in contour has a long history in psychology (Gómez-Puerto, Munar, & Nadal, 2016; Silvia & Barona, 2009).

Early work suggested that the perceived beauty of curves might result from the feelings they evoke, such that “curves are in general

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felt to be more beautiful than straight lines” (Gordon, 1909, p. 169). The robustness of this effect has now been established across a wide range of stimuli including lines, abstract patterns and geometric figures, as well as real objects (Bar & Neta, 2007; Bertamini, Palumbo, Gheorghes, & Galatsidas, 2016; Palumbo & Bertamini, 2016; Salgado-Montejo, Tapia Leon, Elliot, Salgado, & Spence, 2015; Velasco et al., 2016; Westerman et al., 2012). Confirming the findings of early experimentalists, people appear to associate curvilinear contour with positive and pleasant emotions (Dazkir & Read, 2012; Leder & Carbon, 2005; Vartanian et al., 2013).

Particularly important is work generalizing this effect across age groups, cultures, and species. Infants look at round shapes for longer periods than angular shapes, suggesting that interest in rounded objects is present early in life (Jadva, Hines, & Golombok, 2010; Quinn, Brown, & Streppa, 1997). In turn, participants from Oaxaca (Mexico) and Bawku (Ghana)—two small-scale societies relatively uninfluenced by western culture—have also been shown to exhibit a preference for objects with curved contours, as have participants from Mallorca (Spain; Gómez-Puerto et al., in press). Finally, both humans and the great apes prefer objects with curved contour, although in humans the effect is stronger under brief presentations (Munar, Gómez-Puerto, Call, & Nadal, 2015; see also Palumbo & Bertamini, 2016), and when the objects are presented as images with low rather than high spatial frequency information (Bar & Neta, 2007). Greater viewing time and image detail appear to trigger top-down processes that can alter the initial, rapid response to contour.

Contour, Architecture, and Design

A number of studies have extended this effect to architecture and interior design. In one study, participants exhibited a strong aesthetic preference for airport passenger areas with curvilinear roofs and layouts (van Oel & van den Berkhof, 2013), whereas in another study curvilinear interior settings elicited higher degrees of pleasant emotions and a desire to approach those spaces (Dazkir & Read, 2012). In turn, using data collected in a functional MRI (fMRI) study, Vartanian et al. (2013) demonstrated that curvilinear spaces were more likely to be judged as beautiful and pleasant than rectilinear spaces, and that viewing curvilinear spaces activated the anterior cingulate cortex—a structure in the brain’s core emotion network that is responsive to the reward properties and emotional valence of objects. Thus, affect appears to contribute to aesthetic preference for curvilinear spaces. However, in Vartanian et al.’s (2013) study contour had no effect on approach-avoidance decisions, suggesting that curvilinear contour might not necessarily increase one’s motivation to enter a space.

Individual Differences

Recently researchers have begun to examine whether preference for curved design is moderated by individual differences known to be relevant in aesthetic choices. Cotter, Silvia, Bertamini, Palumbo, and Vartanian (2017) investigated the effects of artistic expertise (Smith & Smith, 2006) and openness to experience (using multiple measures including NEO-FFI, Costa & McCrae, 1992) on aesthetic preference using two sets of stimuli: abstract unfamiliar shapes consisting of randomly generated polygons, and

circles and hexagons from the Preference for Balance Test (Wilson & Chatterjee, 2005). In addition, for each stimulus they collected data on both pleasantness as well as interest because low-level features of visual stimuli such as complexity and familiarity have been shown to affect those responses differently (Berlyne, 1971; Marković, 2012; Silvia & Kashdan, in press). Consistent with previous studies, the results demonstrated that people found curved stimuli more pleasant than angular stimuli. In terms of individual differences, earlier studies had shown that in comparison to novices, experts in the visual arts are affected less by low-level visual features and more by compositional and historical features of artworks (e.g., Cleeremans, Ginsburgh, Klein, & Noury, 2016; Locher, 1996; Lundy, 2010; Parsons, 1987; Silvia, 2013). Thus, Cotter et al. (2017) expected to observe an attenuated sensitivity to contour among experts. In fact, the opposite pattern was observed: when the stimuli consisted of abstract unfamiliar shapes, individuals higher in artistic expertise or openness to experience showed greater preference for curved over angular stimuli. This pattern was not evident for the special case of circles and hexagons, likely because such stimuli are accompanied by a set of established semantic associations (e.g., valence) that are known to take precedence over curvature (Leder, Tinio, & Bar, 2011). The results of Cotter et al. (2017) demonstrated that individual differences relevant to aesthetics such as artistic expertise and openness to experience play a role in moderating the effect of contour on preference—insofar as the ratings concern pleasantness. In contrast to pleasantness ratings, contour had no effect on interest ratings. Given that interest’s physiological and expressive components are associated with approach-oriented action (Libby, Lacey, & Lacey, 1973; Silvia, 2008), the results of Cotter et al. (2017) suggest that despite increasing one’s assessment of an object as pleasant, contour might not necessarily increase one’s propensity to approach it.¹ In this sense, their results are consistent with the findings of Vartanian et al. (2013) who also found a dissociation between the effects of contour on beauty judgments versus approach-avoidance decisions.

Present Study

Here we tested the hypothesis that under free viewing conditions, the effect of contour on aesthetic judgments and approach-avoidance decisions would be moderated by expertise in architecture and design. Whereas in previous work the effect of expertise on preference for contour had been assessed using domain-general measures of artistic expertise and experience (Cotter et al., 2017), here we asked people who self-identified as architects and designers on the one hand, and participants with no expertise in these fields on the other, to rate pictures of spaces varying in contour as beautiful or not beautiful, and to decide whether they would opt to enter or exit them. We opted to focus on beauty judgments for the sake of consistency with Vartanian et al. (2013), with the understanding that beauty judgments represent one of many types of

¹ Here it is important to note that we do not consider interest and approach-avoidance to be identical constructs. Specifically, according to functional approaches, emotions help people manage fundamental goals (Lazarus, 1991). One of interest’s functions is perceived to be the motivation to explore (Silvia, 2008). In this sense interest can be perceived as a precursor to approach behavior, but not identical to it.

judgment that one can focus on in studies of aesthetic choice (e.g., liking, preference; see Leder, Augustin, & Belke, 2015).

Of course, degree of expertise in architecture can vary greatly, ranging from people who are registered and practicing architects and/or designers to people who do not hold a degree in architecture, but share an interest in the built environment as a professional colleague, enthusiast or student of architecture and design. This explains an important distinction in the literature between experts and *quasi-experts*—defined as people with some but not the highest level of background and training in the domain (Kozbelt & Kaufman, 2014; see also Silvia, 2006). This difference between experts and nonexperts is also reflected in the membership categories of the *American Institute of Architects* (AIA; see Vartanian et al., in press). In the present study the expert group consisted exclusively of participants who self-identified as architects or designers. In other words, they can be considered experts rather than quasi-experts.

Indeed, architects and nonarchitects have been shown to differ in their affective responses when assessing the aesthetic value of buildings (Kirk, Skov, Christensen, & Nygaard, 2009), although whether such expertise-related differences are influenced by contour remains unknown. We predicted that when the task is to judge the beauty of spaces, contour would have a greater effect on judgments in experts than nonexperts (H1). This would extend the findings of Cotter et al. (2017) to the domain of architecture and design by demonstrating greater sensitivity to contour among experts when judging beauty. In contrast to beauty judgments, however, we did not have a strong a priori prediction regarding how expertise would moderate willingness to enter or exit spaces. Given that in people with no expertise in architecture or design, contour had been shown not to affect approach-avoidance decisions (Vartanian et al., 2013), coupled with the insensitivity of interest ratings to contour, artistic expertise, or openness to experience (Cotter et al., 2017), we did not expect to find an effect of contour on willingness to enter or exit spaces in people with or without expertise in architecture and design (Hypothesis 2 [H2]).

Method

The study received formal approval from the organizers of IIDEX2014—Canada’s largest annual design and architecture exposition and conference in 2014. It also received ethics clearance from the institutional review board of the University of the Balearic Islands.

Participants

Data were collected from two groups of participants. One, the expert group, consisted of people with professional expertise in the design of interior or exterior architectural spaces. In other words, everyone in the expert group self-identified as an architect or a designer at the time of the study. The other, the nonexpert group, included people with no expertise—professional or otherwise—in the design of interior or exterior architectural spaces.

Expert group. This group included 71 designers and architects (sex: 45 female, 21 male, 5 unspecified; education (completed): 14 college, 43 undergraduate, 12 graduate school, 2 unspecified; age: 80% in the 21–60 range) who attended a seminar conducted by the first author entitled *Neuroscience of Design* at

IIDEX2014. Everyone in this group self-identified as an architect or a designer at the time of the study. Upon arrival at the seminar site attendees had the option of collecting a booklet at the entrance that included the experimental material, including instructions. Prior to the start of the seminar attendees who consented to the use of their data for analysis were asked to deposit their booklets into a cardboard box. The cardboard box was collected by an IIDEX2014 employee prior to the beginning of the aforementioned seminar.

Nonexpert group. This group included 71 undergraduate and graduate students (sex: 45 female, 26 male; education (completed): 66 college, 4 undergraduate, 1 graduate school; age: 87% in the 21–60 range) attending psychology, education, and pedagogy courses at the University of the Balearic Islands. Participants in this group were not familiar with the principles of interior or exterior architecture or design, nor had they taken part in any art history courses. Participants were approached in the institution’s halls and invited to take part in the study. No reward of any kind was given for their participation.

Materials and Procedure

Each participant rated the same eight images, selected from the larger pool administered in Vartanian et al. (2013). Each stimulus was printed on a separate page in a booklet. All stimuli appeared in color. There was no time limit to registering a response.

Four images were rated on a dichotomous beauty scale (beautiful—not beautiful) and four images on a dichotomous willingness to enter scale (enter–exit). The decision to use dichotomous scales for each dependent variable was made because the same scales had been used in Vartanian et al. (2013) to collect data from the same subset of stimuli. The order of beauty and willingness to enter blocks within the booklets was counterbalanced across participants. The assignment of the two sets of four images within the beauty and willingness to enter blocks was counterbalanced across participants.

Results

Analytic Approach

We analyzed the effects of interior space contour (curvilinear vs. rectilinear) and expertise (nonexpert vs. expert participants), taking into account task order (beauty first vs. willingness to enter first) on participants’ responses in the beauty judgment and willingness to enter tasks using generalized linear mixed effects models (Hox, 2010; Snijders & Bosker, 2012). This method accounts simultaneously for the between-subjects and within-subjects effects of the independent variables (Baayen, Davidson, & Bates, 2008). It is thus especially suitable for studies of aesthetics, where people may differ considerably in their responses to different stimuli (Brieber, Nadal, Leder, & Rosenberg, 2014; Cattaneo et al., 2015; Silvia, 2007). For this study, linear mixed effects models were used to analyze the impact of contour, and expertise, as well as their interaction, on beauty and enter-exit responses. Additionally, to control for the effects of task order, we also included this variable in both models (beauty judgment and willingness to enter). All predictor variables were categorical, and the reference levels were nonexpert for expertise, rectilinear for contour, and

beauty–enter for task order. All predictor variables were successive difference coded. In setting up the model, we followed Barr, Levy, Scheepers, and Tily's (2013) guidelines. They suggested modeling the maximal random effects structure justified by the experimental design, which, in addition to avoiding the loss of power and reducing Type I error, enhances the possibility of generalizing results to other participants and stimuli. Thus, both models included the interaction between contour and expertise, as well as the control variable task order, as fixed effects, and random intercepts and slope for contour within participants. All analyses were carried out within the R environment for statistical computing (R Development Core Team, 2008), using the `glmer()` function of the `lme4` package (Bates, Maechler, & Bolker, 2013). The `lmerTest` package (Kuznetsova, Brockho, & Christensen, 2012) was used to estimate the p values for the t test based on the Satterthwaite approximation for degrees of freedom.

Beauty

The model revealed a significant main effect of contour ($b = .847, z = 4.856, p < .001$), indicating that there was a significantly higher probability for participants to find curvilinear interior spaces (.65, 95% CI [.59, .70]) beautiful than rectilinear interior spaces (.44, 95% CI [.38, .50]). There was also a significant main effect of expertise ($b = -.403, z = 2.311, p = .021$), indicating that nonexpert participants were more likely to rate the images as beautiful (.60, 95% CI [.54, .66]) than expert participants (.50, 95% CI [.44, .56]). However, these main effects were qualified by a significant interaction between contour and expertise ($b = .870, z = 2.493, p = .013$), indicating that the effect of contour was weaker for nonexpert participants than for expert participants (see Figure 1). Specifically, the difference between nonexpert participants' responses to curvilinear (.65, 95% CI [.57, .72]) and recti-

linear (.55, 95% CI [.46, .63]) interior spaces did not differ from each other ($b = .412, z = 1.691, p = .091$). In contrast, expert participants regarded as beautiful a significantly greater proportion ($b = 1.282; z = 5.134; p < .001$) of curvilinear interior spaces (.66, 95% CI [.57, .73]) than rectilinear interior spaces (.35, 95% CI [.27, .43]). Task order had no effect on participants' responses in the beauty task ($b = -.002, z = 0.140, p = .889$). An analysis using Cook's D found no outlier or influential cases among participants.

Willingness to Enter

The linear mixed effects model revealed a significant main effect of contour ($b = .461, z = 2.646, p = .008$), indicating that participants were significantly more likely to opt to enter curvilinear interior spaces (.66, 95% CI [.60, .71]) than rectilinear interior spaces (.55, 95% CI [.49, .60]). The main effect of expertise was not significant ($b = -.290, z = 1.665, p = .096$). However, the main effect of contour was qualified by a significant interaction between contour and expertise ($b = -.865, z = 2.482, p = .013$), indicating that the effect of contour was weaker for expert than for nonexpert participants (see Figure 2). Specifically, the difference between expert participants' responses to curvilinear (.57, 95% CI [.49, .65]) and rectilinear (.56, 95% CI: .48, .64) interior spaces was not significant ($b = .031, z = 0.126, p = .899$). In contrast, nonexpert participants were willing to enter a significantly greater proportion ($b = .894, z = 3.529, p < .001$) of curvilinear interior spaces (.73, 95% CI [.65, .80]) than rectilinear interior spaces (.53, 95% CI: [.45, .61]). Task order had no effect on participants' responses to the enter task ($b = .004, z = 0.024, p = .981$). Again, an analysis of outlier and influential cases using Cook's D identified no such cases.

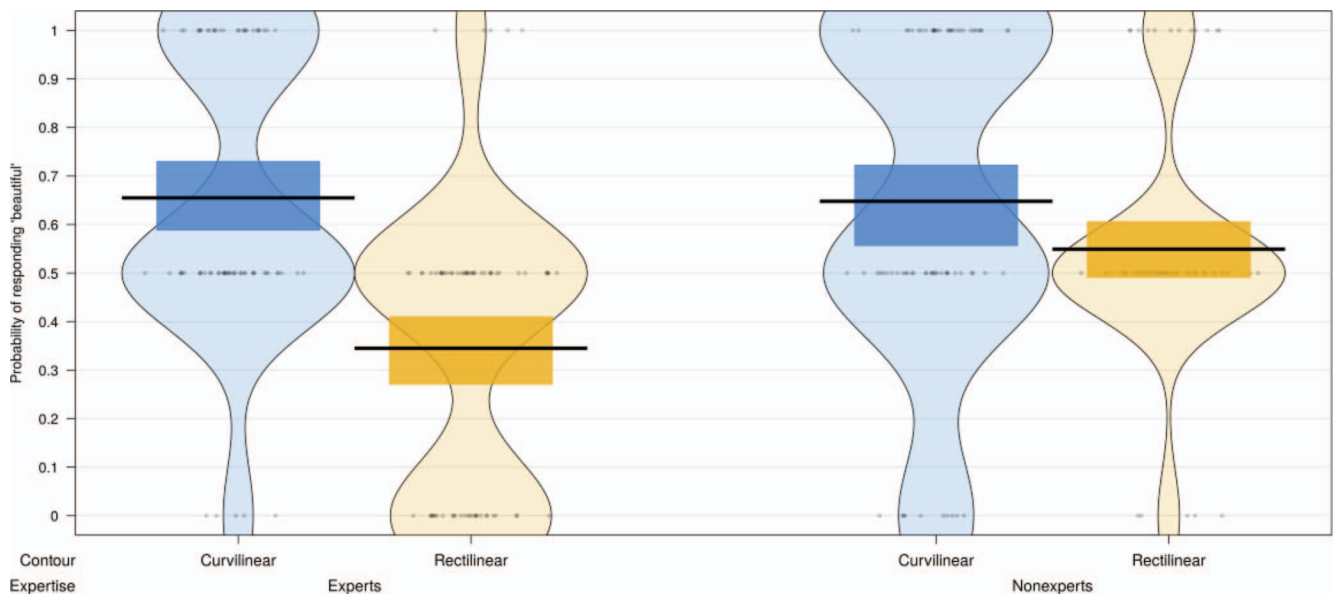


Figure 1. Effect of contour on beauty judgments of architectural spaces. This graphic was created using package `yarr` (Phillips, 2017). See the online article for the color version of this figure.

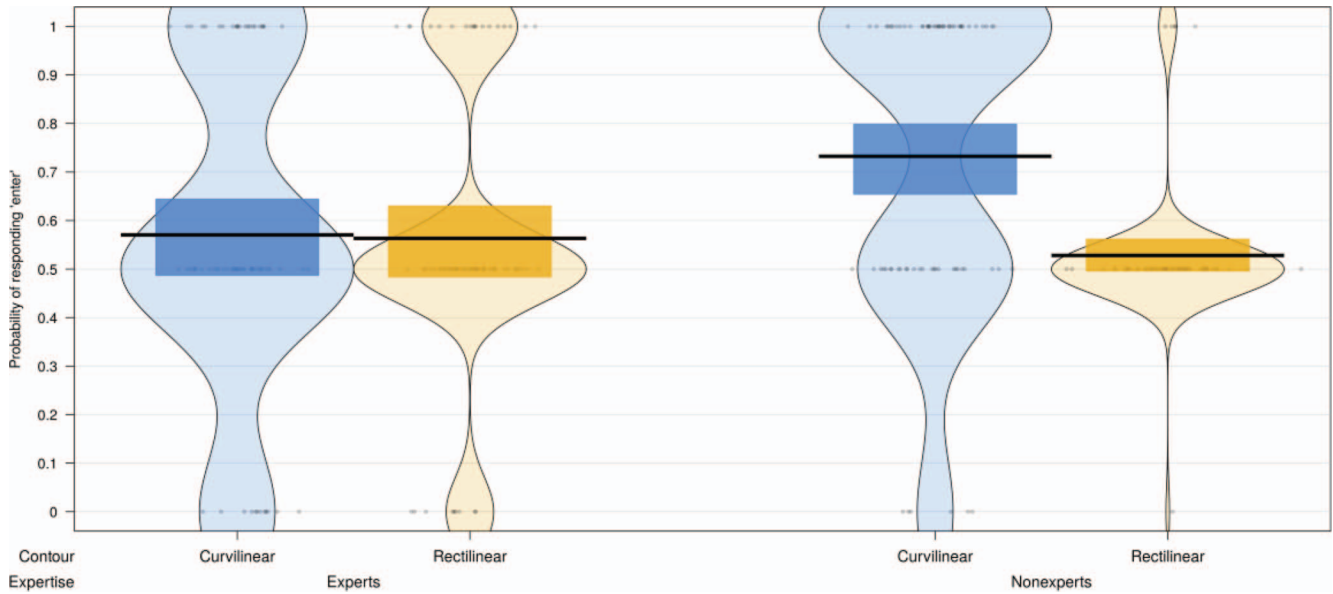


Figure 2. Effect of contour on willingness to enter architectural spaces. This graphic was created using package *yarr* (Phillips, 2017). See the online article for the color version of this figure.

Discussion

People prefer curvilinear over rectilinear contours across a remarkably diverse set of stimuli (see Gómez-Puerto et al., 2016; Silvia & Barona, 2009). Recent work suggests that preference for curvilinear contour is moderated by individual differences relevant to aesthetics, such as artistic expertise and openness to experience (Cotter et al., 2017). Specifically, people with greater levels of artistic expertise and openness to experience are more sensitive to the effect of contour when judging the pleasantness of abstract unfamiliar shapes. Building on recent findings, our aim in the present study was to determine whether preference for curvilinear contour would be similarly moderated by expertise in architecture and design, and whether expertise in this domain would also moderate willingness to enter spaces.

Across all participants, our results replicated previous findings by demonstrating that people find curvilinear spaces more beautiful than rectilinear spaces. In addition, unlike what was observed in a previous study involving architectural stimuli (Vartanian et al., 2013), the present results also demonstrated that nonexpert participants were more likely to indicate a willingness to enter curvilinear than rectilinear spaces. Our results also showed that expertise fundamentally moderates both beauty judgments and the willingness to enter spaces, and that it impacts these choices in dissociable ways. When assessing beauty, experts were more sensitive to contour than nonexperts. Specifically, as predicted (i.e., Hypothesis 1), experts in architectural design found rectilinear spaces less beautiful than curvilinear ones, while contour had no effect on judgments of beauty among nonexperts (see Figure 1). There could be different reasons that underlie experts' greater sensitivity to contour in the context of judging beauty. One possibility is that as designers of spaces, contour is a more salient variable to architects and designers than it is to nonexpert participants. Another possibility is that among experts, greater sensitivity to contour could be

a function of negative associations toward rectilinear contours (see Bertamini et al., 2016; Palumbo, Ruta, & Bertamini, 2015), honed through professional practice and training. Importantly, these two possibilities are not mutually exclusive, and their relative contributions can be examined in future studies.

In contrast, contrary to our expectation (H2), when participants were asked to indicate their willingness to enter or exit the depicted spaces, contour had a large influence on nonexperts' responses but no effect on experts' responses (see Figure 2). In terms of approach-avoidance decisions, these results demonstrate that participants with no formal training in architecture and design are affected more than experts by the affordances of curvilinear contour. The reason for this difference is not clear. Perhaps when prompted to make an enter-exit decision, the functionality or usability of a space becomes the relevant frame for choice for nonexpert participants. Experts may be trained to view images of architectural spaces dispassionately and be less subject to implicit behavioral biases rendered by their visual features (see Woods, Kranjec, Lehet, & Chatterjee, 2015).

Interestingly, unlike what was observed in Vartanian et al. (2013), whereas contour did not influence nonexperts' choices in the beauty judgment condition, it had a large influence on their choices in the approach-avoidance condition. A number of methodological considerations could account for these differences. First and foremost, in Vartanian et al. (2013) the response window was limited to three seconds, whereas in the present study there was no time limit for making choices. It is possible that greater viewing time might trigger top-down processes that can alter the initial, rapid response to contour (see Munar, Gómez-Puerto, López-Navarro, & Nadal, 2014), and that the direction of this alteration might vary as a function of the task under consideration (i.e., beauty judgment vs. approach-avoidance decisions). In addition, the two studies differed in the number of stimuli presented to

the participants (i.e., 200 vs. 8), as well as the settings in which the data were collected (i.e., inside the fMRI vs. IDEX and the University of the Balearic Islands). Our findings suggest that despite its relative robustness, the effect of contour remains sensitive to methodological variations.

An important question that remains unanswered is why people prefer curvilinear contour across studies. In their comprehensive review of this literature, Gómez-Puerto et al. (2016) identified several sources (and related mechanisms and processes) that could contribute to preference for curvature. They noted that explanations offered to date could be broadly categorized under sensorimotor-based explanations and appraisal-based explanations. According to the former “preference for curvature derives from the way in which physical properties of curved stimuli directly interact with specific characteristics of the sensorimotor system” (Gómez-Puerto et al., 2016, p. 2). In other words, we owe our preference for curvature to a coupling between this perceptual feature (i.e., curved configuration) and sensorimotor processes attuned to it in the brain. In contrast, appraisal-based explanations have emphasized the ways in which nonrepresentational semantic meaning associated with curvature can implicitly or explicitly elicit emotional evaluations in people. As noted by Gómez-Puerto et al. (2016), whereas sensorimotor-based explanations have come in many different varieties—focusing on movement, neural activity, fluency, and gestalt principles—appraisal-based explanations show more consistency and thematic uniformity across studies. Nevertheless, there is some supporting evidence in favor of both categories of explanations, and additional research is needed to isolate the mechanism(s) responsible for the observed effect.

A number of limitations must be taken into account when evaluating the results of the present study. First and foremost, our data were collected from a relatively small number of stimuli. The main reason for our decision to limit the number of stimuli was to facilitate data collection from architects and designers outside of the laboratory setting. As such, the reliability of the results reported here must be determined in future studies involving a larger number of stimuli. Second, in the present study we opted to use dichotomous scales to collect data on beauty judgments and approach-avoidance decisions. Past research in this area has employed a wide variety of response options, including dichotomous scales (e.g., Vartanian et al., 2013) as well as scales with more gradations (Cotter et al., 2017). Arguably, more fine-grained responses could be collected based on scales that offer more than two options, although the effect that a different scale might have on the pattern of results observed here would have to be examined empirically in the future. Finally, despite using a similar procedure, the context within which data were collected from experts and nonexperts also varied. Future studies could aim to collect data from both groups under identical conditions to minimize possible contextual effects on the outcomes of interest.

In sum, whereas the contour of interior architectural spaces seems to be more relevant to experts in terms of this feature’s aesthetic impact, it seems to be more relevant to nonexperts in terms of its motivational impact. Thus, expertise in interior architecture appears to heighten contour’s status as a design feature, but attenuates the role it plays in approach-avoidance decisions. Alto-

gether, our results bolster the case for the importance of contour as an important and potentially adaptive visual feature in architecture and design, but also stress the impact that expertise has on its aesthetic and motivational relevance.

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