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Type of Art Expertise Matters: Practical Experts Show a Greater Curvature Preference for Three-Dimensional Shapes Than Theoretical Experts

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Among the single factors influencing aesthetic preference, curvature has robust empirical evidence across age, culture, and species. Recent studies have examined whether the preference for curvature extends to experts. Although it has been reported that experts also prefer curved shapes to angular ones, it remains unclear whether their degree of preference for curvature differs from that of nonexperts. The inconsistency might be because of variabilities in expert groups and types of stimuli. Here, we investigated whether experts prefer curvature over angularity and whether the degree of curvature preference differs across expert groups (i.e., nonexperts, practical experts, and theoretical experts). In addition, we examined whether the preference for curvature derives from the evaluation of stimulus curvature. We generated geometric three-dimensional (3D) shapes rendered by a parametric shape model, not limited to any specific domain of expertise. The curvature of 3D shapes was manipulated into five levels via linear interpolation. Participants viewed video clips of each 3D shape and rated their preference and the extent of curvature for each shape. Results showed that people generally prefer curved shapes, regardless of expertise groups, replicating previous findings. Of more relevance to our purpose, people with more practical expertise exhibited a greater preference for curved shapes, and this preference was associated with their evaluation of curvature. These results suggest that the degree of curvature preference varies depending on the presence and type of expertise, highlighting the importance of considering the expertise type when investigating its influence.

Keywords: curvature, preference, expertise, three-dimensional shape

Supplemental materials: https://doi.org/10.1037/aca0000746.supp

Among single factors influencing aesthetic preference, curvature has a substantial body of robust empirical evidence. People prefer curvature over angularity in various kinds of visual stimuli, including lines (Bertamini et al., 2016; Hevner, 1935; Lundholm, 1921; Poffenberger & Barrows, 1924), geometric shapes (Bertamini et al., 2016; Fantz & Miranda, 1975; Jadva et al., 2010; Palumbo & Bertamini, 2016; Palumbo et al., 2015; Silvia & Barona, 2009; Velasco et al., 2016), daily objects (Bar & Neta, 2006; Corradi et al., 2019), and practical designs (product, Westerman et al., 2012; car interior, Leder & Carbon, 2005; furniture, Dazkir & Read, 2012; and interior architecture, Vartanian et al., 2013, 2019). The preference for curvature has also been observed across age (Fantz & Miranda, 1975; Jadva et al., 2010), culture (Gómez-Puerto et al., 2018), and species (Munar et al., 2015). This evidence suggests that curvature preference can be regarded as a universal and robust response. Then, is the preference for curvature not influenced by other factors that individuals have?

Recent studies have focused on whether the preference for curvature extends to art experts (Corradi et al., 2019, 2020; Cotter et al., 2017; Ho et al., 2016; Leder & Carbon, 2005; Silvia & Barona, 2009; Vartanian et al., 2019). Although the results of the previous studies demonstrated that experts prefer curved shapes to angular ones, it remains inconsistent whether the degree to which they prefer curvature differs from nonexperts. For example, some studies have found that experts show a stronger preference for curvature (Ho et al., 2016; Leder & Carbon, 2005; Vartanian et al., 2019), while others have found a weaker preference (Corradi et al., 2020; Silvia & Barona, 2009), or no difference compared to nonexperts (Corradi et al., 2019, 2020; Cotter et al., 2017).

Previous studies have included expertise from various domains, including design, architecture, and art history (Corradi et al., 2019; Ho et al., 2016; Vartanian et al., 2019). However, it is important to note that expertise from these different domains is likely to vary in terms of trained abilities. Art expertise, regardless of its specific domain, can be categorized into two distinct types according to the characteristics of trained abilities: practical and theoretical expertise. Specifically, practical experts, particularly designers, convert given requirements into completed products or solutions (Demir et al., 2021; Kress & Van Leeuwen, 2020). To achieve this, they create multiple drafts and prototypes using various graphic tools and software, refining visual elements based on feedback. This process relies heavily on perceptual and motor skills (Benear et al., 2024; Gowen & Miall, 2006; Kozbelt & Seeley, 2007; Razzouk & Shute, 2012). On the other hand, theoretical experts

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such as art theorists/historians and curators delve into research on artworks, artists, and movements, utilizing books, archival materials, and academic papers. They offer interpretations and evaluations of embedded narratives and meanings in artworks, sharing their insights with broader audiences. This process draws primarily on their cognitive and theoretical knowledge (Bilalić, 2017; Gobet, 2017). Indeed, some studies that recruited practical experts such as designers and architects demonstrated that their preferences showed greater variations depending on the perceptual feature dimension, specifically curvature (Ho et al., 2016; Vartanian et al., 2019). Therefore, the type of expertise might be a potential reason behind the inconsistent results.

Viewing the previous research from this angle, some studies that recruited architects and designers, regarded as practical experts, utilized images of architectural and interior spaces as well as mobile device designs that belong to their domain of expertise (Ho et al., 2016; Palumbo et al., 2022; Vartanian et al., 2019). In contrast, a previous study presented participants majoring in art history, considered theoretical experts, with everyday objects, such as mirrors and baskets, which are not related to their expertise (Corradi et al., 2019). In addition to the expertise type, it is possible that whether the domain-specific stimuli were utilized or not may have been involved in the conflicting findings of previous studies. To compare the influence of both practical and theoretical expertise in a single study using the same stimuli, it is necessary to use domain-general geometric shapes with the curvature feature manipulated, rather than stimuli specific to a certain domain of expertise.

In addition to the geometric shapes, the dimensionality of the shape is also noteworthy in terms of shape characteristics. Previous studies that examined the curvature preference of experts using geometric shapes employed two-dimensional (2D) ones (Cotter et al., 2017; Silvia & Barona, 2009). Additionally, existing research in empirical aesthetics has generally neglected aesthetic preference for three-dimensional (3D) shapes. Nevertheless, 3D shapes are important in artistic and aesthetic contexts such as sculpture and design. Exploring our aesthetic responses to 3D shapes is critical for understanding the multifaceted nature of aesthetic experiences. Therefore, in this study, we aimed to examine whether the preference for curvature differs among the three expertise groups (i.e., nonexperts, practical experts, and theoretical experts), with a particular focus on the degree of preference, using geometric 3D shapes.

Besides examining tentative differences in aesthetic preference, understanding why experts and laypeople differ in the extent to which the variation of the visual properties influences their aesthetic preference has the potential to shed light on the process of aesthetic evaluation itself (Corradi et al., 2019; Stich et al., 2007). One approach to understanding the underlying mechanism of experts' preferences is to investigate their perceptual abilities (Benear et al., 2024). For instance, it has been shown that aesthetic judgments regarding visual properties are likely influenced by the evaluation of the visual properties. Previous studies have demonstrated that experts perceive a shape as more rounded with just a hint of roundness compared to nonexperts (Ho et al., 2016), and that people with more art experience exhibit greater perceptual sensitivity to curvature (Clemente et al., 2023). Therefore, it is plausible that experts' evaluation of the visual properties may be closely associated with the degree of preference along the variation of the visual properties. By investigating the relationship between aesthetic preference and curvature evaluation, we aimed to explore the underlying mechanism of aesthetic preference along the curvature-angularity dimension.

Taken together, this study aimed to examine whether the degree of curvature preference varies based on the type of expertise (i.e., nonexperts, practical experts, and theoretical experts) using geometric 3D shapes, and whether the dissimilar patterns of curvature preference among the three groups are connected with their evaluations of curvature. In light of previous findings demonstrating that both experts and novices prefer curved shapes over angular ones, and that experts in architecture and design exhibit greater variation in their aesthetic evaluations along the curvature-angularity dimension (Ho et al., 2016; Vartanian et al., 2019), we hypothesized that curved shapes are preferred across all expertise groups, and that practical experts show a stronger preference for curvature compared to nonexperts and theoretical experts. Additionally, practical experts are likely to consider the influence of shape characteristics, particularly curvature, on users because of its direct link to usability and safety (Bölte et al., 2017; Leder & Carbon, 2005). Building on this and based on a previous study reporting differences in curvature evaluation by practical experts (Ho et al., 2016), we also hypothesized that the stronger preference for curvature among practical experts is derived from their evaluations of curvature.

To test these hypotheses, we recruited nonexperts and well-trained experts, including both practical and theoretical experts, and assessed their expertise levels. It enabled us to clearly establish the validity of the expert groups and examine the relationship between the level of expertise, preference, and curvature evaluation on a continuous scale. Additionally, we generated geometric 3D shapes and parametrically manipulated the curvature of the shapes into five levels. It allowed us to examine whether there are systematic changes in preference according to that continuous dimension of curvature, which could not have been observed with binary dimension. Participants rated their preference and the extent of curvature for each geometric 3D shape.

Method

Participants

Data were collected from two participant groups: the nonexperts and the experts. The nonexpert group comprised individuals with no prior background in art. Meanwhile, the expert group was categorized into two subgroups, namely practical and theoretical expert groups. We performed a power analysis using G*Power 3 software (Faul et al., 2007). Based on a recent meta-analysis showing that the curvature effect has a medium effect (Hedges' $g = 0.39$), we calculated the minimum required sample sizes for mixed analysis of variance (ANOVA) and multiple linear regression, which are our main analyses, using a medium effect size. For the mixed ANOVA analysis, the minimum required sample size was found to be 27 participants in total (effect size $f = 0.25$, $\alpha = .05$, power = .80). For the multiple linear regression, the minimum required sample size was found to be a total of 43 participants (effect size $f^2 = 0.15$, $\alpha = .05$, power = .80). In line with the suggestions for online studies (Sauter et al., 2020; Stewart et al., 2017), we increased the sample size twofold. Finally, we recruited 92 participants in total (for more details on each expertise group, refer to the main text below or Table 1). Participants in the nonexpert group were recruited by posting a recruitment notice on the community platform of Korea University. Participants in expert groups were recruited by posting a recruitment notice on a website commonly visited by art-related experts. At the beginning of the online survey, there was a question asking about the participants'

Table 1
Descriptive Statistics for Participants

Demographics	Nonexpert	Practical expert	Theoretical expert
Age (*SD*)	26.7 (3.0)	27.8 (2.7)	26.7 (4.1)
N (gender)	30 (5 M, 25 W)	33 (4 M, 29 W)	29 (4 M, 25 W)
Comprisal	30 graduate students	26 designers, 7 graduate students	7 curators, 13 graduate students, 9 undergraduate students

Note. M = men; W = women.

occupations. For those with practical expertise, the survey proceeded only if they were designers or graduate students majoring in design. As for those with theoretical expertise, the survey proceeded only if they were curators, graduate students, or undergraduate students (only juniors and seniors) majoring in art history-related fields. No statistical difference in age across the three groups was observed, $F(2, 89) = 1.25$, $p = .29$. All participants had normal or corrected-to-normal vision. Informed consent was obtained from all participants following the procedures approved by the Institutional Review Board of Korea University (KUIRB-2021-0346-01). All participants received compensation for their participation.

Nonexpert Group

This group consisted of 30 graduate students from various majors who had no formal training in art, such as humanities, social sciences, engineering, etc. The specific majors of nonexperts are shown in Table S1 in the online supplemental materials.

Practical Expert Group

This group consisted of 33 participants, including designers (average of 2.75 years of work experience) with expertise in user experience/user interface, graphic, and product design, as well as graduate students majoring in design such as industrial and visual design. Table S2 in the online supplemental materials details the specific fields and job roles of practical experts.

Theoretical Expert Group

This group consisted of 29 participants, comprising curators (average of 2 years of work experience), the majority of whom held a master's degree related to art history and art theory, as well as graduate students and undergraduate students (only including juniors and seniors) majoring in art history, art theory, or aesthetics. Table S3 in the online supplemental materials provides details on the specific fields and job roles of theoretical experts.

Expertise Questionnaire

We used two different questionnaires to assess both practical and theoretical expertise. The Art Experience Questionnaire (AEQ; Chatterjee et al., 2010) was utilized to evaluate practical expertise, while the Vienna Art Interest and Art Knowledge (VAIAK; Specker et al., 2020) was employed to evaluate theoretical expertise.

The AEQ is a widely used questionnaire for measuring art experience and expertise although its reliability or validity has not yet been reported (Corradi et al., 2019; Darda & Cross, 2022; Song et al., 2021). The AEQ is composed of eight items on classroom experience in studio art, art history, art theory or aesthetics, frequency of visits to museums and galleries, and average weekly time committed to creating, reading, and viewing. Although we utilized the last three items related to activities, as our focus was on verifying practical expertise, we included only one item "creating" (e.g., "In the average week how many hours do you spend making visual artworks or creating a piece that is related to art?") in the analysis.

The VAIAK is composed of two separate scales: an art knowledge scale (Part B: 6 multiple choice questions about knowledge of iconography and techniques; Part C: 20 open-ended questions about categorizing styles and artists) and an art interest scale (Part A: 11 multiple choice questions about subjective interest and art-interested behavior). The VAIAK demonstrated high internal consistency reliability (art knowledge scale, $\omega = .85–.89$; art interest scale, $\omega = .94$) and good test–retest reliability (art knowledge scale, $r = .79$; art interest scale, $r = .75$; Specker, 2024; Specker et al., 2020). It also showed adequate validity by way of face validity and content validity although continuing to put effort into validation is recommended (Specker, 2024; Specker et al., 2020). As our interest was in knowledge in terms of assessment of theoretical expertise, we included only the subscale "knowledge" encompassing both Part B and C in the analysis. With the two questionnaires, we aimed to support the division of nonexperts and experts, as well as practical and theoretical experts, and to analyze how participants' level of expertise is associated with their preferences. The scores for the AEQ activity subscales, including creating, and VAIAK, including knowledge, are shown in Table 2.

Stimuli

We produced achromatic 3D geometric shapes using a parametric shape model ("Superformula," Gielis, 2003; Song et al., 2022). Initially, two shapes were generated: one angular and one curved, each with five protruding arms. By employing linear interpolation with the coordinates of the angular and curved shapes (Kwak et al., 2020), three intermediate shapes between the angular and curved ones were created. As a result, a total of five shape models parametrically changing from angular to curved shapes were generated (Figure 1A). To provide a comprehensive view of each shape model, we created video clips that rotated the model through 360° angles for each 3D shape (Movies S1, the most angular stimulus presentation–S5, the most curved stimulus presentation in the online supplemental materials). All shape stimuli were illuminated vertically from 0° and tilted 45° from the vertical line.

Procedures

Before the main experiment, participants' levels of expertise were assessed through questionnaires (i.e., AEQ and VAIAK) conducted via Google Forms (Mountain View, California, United States). Subsequently, the main experiment was performed online using

Table 2

Descriptive Statistics for the Scores of Expertise Questionnaires for Each of the Three Groups

Questionnaire	Item/subscale	Nonexpert	Practical expert	Theoretical expert
AEQ activity subscale	Sum of three items	1.03 (1.90)	25.88 (18.59)	11.46 (9.67)
	Creating	0.37 (0.96)	21.85 (17.12)	3.77 (6.62)
	Reading	0.27 (0.52)	2.62 (3.02)	5.42 (6.98)
	Viewing	0.40 (0.77)	1.42 (1.39)	2.27 (1.82)
VAIAK	Total score of VAIAK	45.83 (15.60)	63.79 (11.83)	82.10 (9.64)
	Knowledge	9.03 (4.00)	12.27 (4.91)	19.86 (3.26)
	Interest	36.80 (12.73)	51.52 (9.16)	62.24 (8.02)

Note. AEQ = Art Experience Questionnaire; VAIAK = Vienna Art Interest and Art Knowledge.

PsyToolkit (Stoet, 2010; 2017). In each trial, participants were presented with a 3D shape video clip for 3 s and then were instructed to respond to the two rating tasks on a 7-point Likert scale: how much they preferred the shape (preference rating task) in the first block and how curved it looked (curvature rating task) in the second block, respectively, as shown in Figure 1B. The order of five trials within the block was randomized. Participants completed a total of 10 trials (2 blocks × 5 shapes). The preference block preceded the curvature block to avoid any potential impacts of exposure to the shape during the curvature rating on the preference judgment.

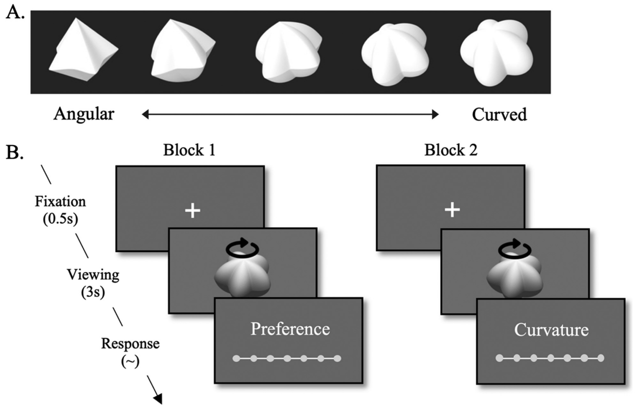
Results

Measures of Expertise

Prior to presenting the main results, it is necessary to evaluate the validity of dividing individuals into each expertise group. One-way ANOVA with the between-factor "expertise" (i.e., nonexperts, practical experts, and theoretical experts) and post hoc independent t tests were conducted. All analyses for this study were conducted using SPSS (Version 27, SPSS Inc., Chicago, Illinois, United States). The false discovery rate (FDR)-correction was applied with $p = .05$ for multiple comparisons (Benjamini & Hochberg, 1995; Benjamini & Yekutieli, 2001). As shown in Figure 2A, it demonstrated that the mean creating score of AEQ was higher among practical experts compared to that of both nonexperts, $t(54) = -6.87$, $p < .001$, FDR corrected, and theoretical experts, $t(50) = 5.02$, $p < .001$, FDR corrected, $F(2, 79) = 33.63$, $p < .001$. In addition, the mean knowledge score of VAIAK was higher among theoretical experts compared to that of both nonexperts, $t(57) = -11.39$, $p < .001$, FDR corrected, and practical experts, $t(60) = -7.07$, $p < .001$, FDR corrected, $F(2, 89) = 52.93$, $p < .001$. There was a significant difference in the mean knowledge score of VAIAK between nonexperts and practical experts, $t(61) = -2.86$, $p < .01$, FDR corrected.

Figure 1

Shape Models (A) and Trial Sequence (B)



Note. The response screens are simplified versions for visualization purposes.

Manipulation Check

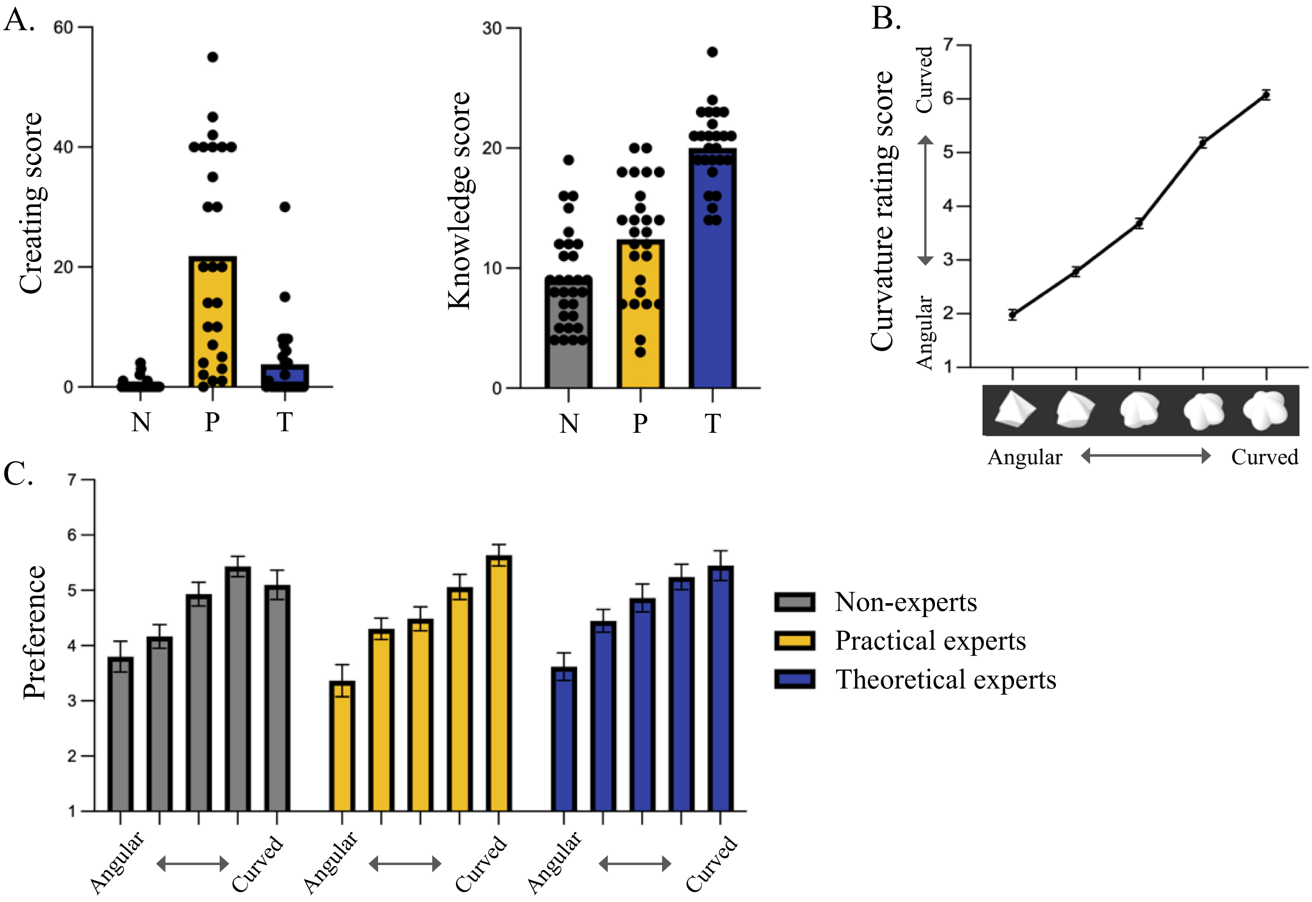
We aimed to verify whether the physical curvature of the stimuli we manipulated aligned with participants' evaluations of the extent of curvature. For this, we conducted a one-way repeated measures ANOVA (RM ANOVA) with the factor "curvature" (i.e., from the first level of the most angular to the fifth of the most curved) and post hoc paired t tests. As illustrated in Figure 2B, the results indicate that participants' evaluations of the extent of curvature reflected the manipulated curvature, $F(2.93, 266.59) = 434.13$, $p < .001$, confirming that the variations of curvature in the stimuli were successfully manipulated.

Aesthetic Preference for Curvature and Expertise

As our primary question, we sought to investigate whether the preference for curvature is modulated by the presence of expertise and its type. We conducted two-way mixed ANOVA with the within-factor "curvature" (i.e., from the first level of the most angular to the fifth of the most curved) and the between-factor "expertise" (i.e., nonexperts, practical experts, theoretical experts) for preference in order to examine whether the mean preference values vary across curvature levels and expertise groups. As shown in Figure 2C, the curvature had a significant main effect on preference, $F(2.94, 262.02) = 45.82$, $p < .001$, $\eta_p^2 = .34$, Greenhouse–Geisser corrected. Neither the main effect of expertise, $F(2, 89) = 0.25$, $p = .78$, nor the interaction effect between the two factors, $F(5.89, 262.02) = 1.47$, $p = .19$, was statistically significant. Post hoc pairwise comparisons using paired t test demonstrated that the most curved shape was preferred the most, and the preference gradually decreased for the most angular shape, first and second level, $t(91) = -4.11$, $p < .001$, Cohen's $d = 0.43$; second and third level, $t(91) = -4.10$, $p < .001$, Cohen's $d = 0.43$; third and fourth level, $t(91) = -3.91$, $p < .001$, Cohen's $d = 0.41$, FDR corrected. These results indicate that people preferred curved shapes to angular ones irrespective of whether one has expertise or not, or

Figure 2

Measure of Expertise (A), Manipulation Check (B), and Results on Aesthetic Preference and Expertise (C)



Note. N, P, and T indicate nonexperts, practical experts, and theoretical experts. See the online article for the color version of this figure.

what type of expertise one has. Additionally, their aesthetic preference systematically varied in accordance with the level of curvature across all expertise groups.

The Degree of Aesthetic Preference, Expertise, and Curvature Evaluation

The group analysis relying on the mean preference values and discrete group division might have obscured individual differences, especially among experts. To closely investigate the link between expertise and the degree of curvature preference, it is critical to analyze how each individual's level of expertise relates to their degree of curvature preference. Furthermore, regarding the underlying reason for aesthetic preference, we hypothesized that the evaluation of curvature would lead to the aesthetic preference. Thus, we conducted multiple linear regressions for all participants without group division to examine whether the degree of aesthetic preference is predicted by their level of expertise and evaluation of the extent of curvature.

To conduct the analyses, we initially fitted a linear function to the preference and curvature rating data for each individual, along the five levels of curvature variation. The coefficient of the function (i.e., the slope of the function) to the preference and curvature rating was extracted. Specifically, a higher value for the preference slope indicated a stronger preference for curvature over angularity. Regarding the curvature slope, a higher value indicated that participants evaluated a shape as more curved with a subtle hint of curvature. In order to include a wide spectrum of time spent on creative activities by experts, we additionally asked participants who indicated spending "more than six hours" on the creating subscale of AEQ to specify the number of hours they spent creating in a week. Seven practical experts who had not provided the requested information were excluded, and 26 practical experts were included in this analysis.

The results of the multiple linear regression analysis with three predictor variables, namely "creating score," "knowledge score," and "curvature slope" and the response variable "preference slope" demonstrated that both the creating score and the curvature slope significantly predicted the preference slope, $F(3, 81) = 4.77$, $p = .004$, $R^2 = .15$; creating, $b = 0.01$, $t = 2.68$, $p = .009$; knowledge, $b = 0.00$, $t = -0.03$, $p = .98$; curvature slope, $b = 0.42$, $t = 3.00$, $p = .004$; see Table 3 for detailed statistics. These results indicate that people with greater experience in creation exhibit a stronger preference for curvature. Moreover, those who find a shape more curved prefer curved shapes more.

Table 3

Results of Multiple Linear Regression Analyses for All Participants

Group	Variable	*b*	*SE*	β	*T*	*p*
All	Creating score	0.01	0.003	.28	2.68	.009**
	Knowledge score	0.00	0.01	−.003	−0.03	.98
	Curvature slope	0.42	0.14	.31	3.00	.004**
	Model statistics	$F(3, 81) = 4.77$, $p = .004$**, $R^2 = .15$				

Note. *b* is an unstandardized coefficient. β is a standardized coefficient.
** $p < .01$.

Despite sharing the same quantitative measures, such as scores of creating and knowledge, qualitative differences stemming from distinctions among expert groups may manifest, resulting in varying influences observed across three expertise groups. Therefore, we performed multiple linear regression analyses for each of the three expertise groups, using the same predictor and response variables as mentioned above. Notably, for practical experts, both the creating score and the curvature slope significantly predicted the preference slope, $F(3, 22) = 3.89$, $p = .02$, $R^2 = .35$; creating, $b = 0.01$, $t = 2.38$, $p = .03$; knowledge, $b = -0.12$, $t = -0.91$, $p = .37$; curvature slope, $b = 0.89$, $t = 2.97$, $p = .007$. However, for both theoretical experts and nonexperts, neither the scores on creating and knowledge nor the curvature slope significantly predicted the preference slope. The results of multiple linear regressions of three groups are summarized in Table 4. Since the current analysis involves four variables, plotting graphs becomes challenging. Nevertheless, in order to enhance understanding through visualization, we illustrated Figure 3 based on additional multiple linear regressions utilizing two predictor variables, namely expertise score (creating score for practical experts, knowledge score for theoretical experts) and curvature slope.

Taken together, the results from all participants were primarily influenced by practical experts. This suggests that qualitative characteristics of experts moderate the relationship between expertise type, aesthetic preference, and curvature evaluation.

Discussion

In this study, we examined whether experts prefer curved shapes over sharp ones and whether the degree of preference for curvature is modulated by expertise and its type, using geometric 3D shapes with varying levels of curvature. As hypothesized, both experts and laypeople showed a preference for curvature to angularity, and the degree of preference was found to be dependent on the type and level of expertise. In addition, we investigated whether the degree of preference reflects the evaluation of stimulus curvature. As hypothesized, we found that the degree of preference was directly linked to the evaluation of stimulus curvature, and this relationship is modulated by the presence and type of expertise.

By demonstrating the distinctive influence according to expertise types, our results provide evidence to clarify conflicting findings on the curvature preference of experts, particularly the degree of curvature preference. This approach allowed us to obtain a more nuanced and comprehensive understanding of the preference for curvature. It underscores the importance of considering the different characteristics of expertise types when examining the effect of expertise on preference for not only curvature but also general aesthetic appreciation.

Furthermore, in terms of the broader context of experts' aesthetic preference, there has been a longstanding controversy about whether expertise is more related to perceptual (e.g., visual features) or cognitive (e.g., interpretation) factors involved in aesthetic appreciation (Cleeremans et al., 2016; Locher, 1996; Lundy, 2010; Parsons, 1987; Silvia, 2013; Song et al., 2021). This study revealed that the type of expertise moderates this relationship. Specifically, our results showed a direct connection between the evaluation of a visual feature (i.e., curvature) and aesthetic preference among practical experts, but not among theoretical experts. In other words, practical expertise was tightly connected to the visual features involved in aesthetic judgment, whereas theoretical expertise did not seem to be as closely related to them. We not only gained a better understanding of experts' curvature preference but also provided insight into the ongoing debate on the role of expertise in aesthetic preference.

Our results demonstrated that both experts and novices preferred curvature as opposed to angularity. These results replicate previous findings and provide further support for the notion that the preference for curved shapes is universal and generalizable across various categories of visual stimuli (Bar & Neta, 2006; Bertamini et al., 2016; Dazkir & Read, 2012; Hevner, 1935; Westerman et al., 2012), experimental paradigms (Palumbo & Bertamini, 2016), cultural backgrounds (Gómez-Puerto et al., 2018), and even across different species (Munar et al., 2015). If we had manipulated the curvature dimension in a binary manner, namely curved or angular, it would have been challenging to rule out the confounding factor where one of the two shapes might be more familiar or have a semantic association with

Table 4

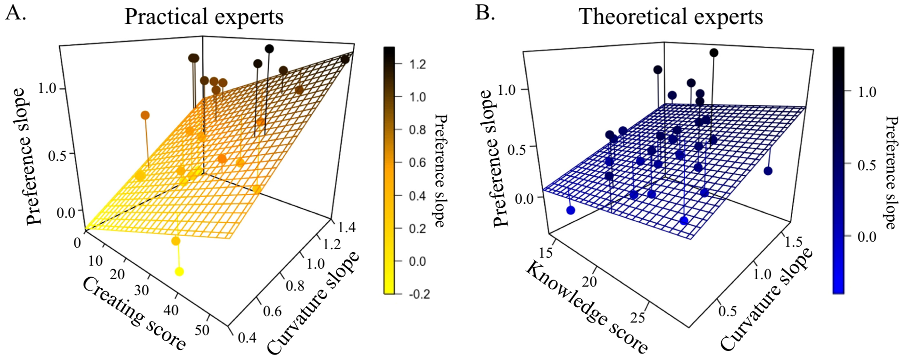
Results of Multiple Linear Regression Analyses for Each of the Three Groups

Group	Variable	*b*	*SE*	β	*T*	*p*
Nonexpert	Creating score	−0.18	0.10	−.38	−1.80	.08
	Knowledge score	−0.02	0.02	−.18	−1.02	.32
	Curvature slope	−0.01	0.32	−.01	−0.03	.98
	Model statistics	$F(3, 26) = 1.98$, $p = .14$, $R^2 = .19$				
Practical expert	Creating score	0.01	0.01	.44	2.38	.03*
	Knowledge score	−0.12	0.02	−.16	−0.91	.37
	Curvature slope	0.89	0.30	.53	2.97	.007**
	Model statistics	$F(3, 22) = 3.89$, $p = .02$*, $R^2 = .35$				
Theoretical expert	Creating score	−0.001	0.01	−.01	−0.07	.94
	Knowledge score	0.02	0.02	.14	0.74	.47
	Curvature slope	0.34	0.19	.34	1.80	.08
	Model statistics	$F(3, 25) = 1.18$, $p = .34$, $R^2 = .12$				

Note. *b* is an unstandardized coefficient. β is a standardized coefficient.
* $p < .05$. ** $p < .01$.

Figure 3

Results of the Expert Groups (Practical [A] and Theoretical [B]) on the Degree of Aesthetic Preference, Expertise, and Curvature Evaluation



Note. The color map represents the values of preference slope, with darker shades of black indicating a stronger preference for curvature over angularity. The regression planes of expert groups (practical, A and theoretical, B) are illustrated using the predictor variables "expertise score (creating score, A and knowledge score, B)," "curvature slope" and the response variable "preference slope." See the online article for the color version of this figure.

a preexisting valence (Cotter et al., 2017). However, by dividing the curvature dimension into five levels and demonstrating the gradual modulation of preference along these multiple levels, we can strongly support that participants' aesthetic preference is attributed to the effect of visual properties, namely curvature-angularity, rather than other confounding factors.

The reason why curved shapes are preferred has been explained from several perspectives: processing fluency, neurophysiology, and learning although none of them provide conclusive explanations (Gómez-Puerto et al., 2016). Curvilinear features, compared to rectilinear ones, have been reported to be processed more quickly and easily, namely perceptually fluent (Bertamini et al., 2019; Reber & Schwarz, 2006; Ruta et al., 2014, 2019; Treisman & Gelade, 1980; Wolfe et al., 1992; Yue et al., 2020). Moreover, curved shapes induced greater activity in a set of cortical cells (Fantz & Miranda, 1975; Hubel & Wiesel, 1968), suggesting that curvature is deeply rooted in our neurophysiological system (Gómez-Puerto et al., 2016). Finally, a sharp contour has a threatening nature as a result of developmental learning and evolutionary origin (Aiken, 1998; Bar & Neta, 2007, 2008).

In terms of the difference in the degree of curvature preference depending on the expertise type, which is more relevant to our main purpose, we found the distinction between practical and theoretical experts: people with more practical expertise showed a stronger curvature preference, while theoretical expertise was not related to the degree of curvature preference. Our findings on practical expertise are consistent with previous studies demonstrating a greater preference for curvature among individuals with practical expertise (Ho et al., 2016; Vartanian et al., 2019). It should be noted that another previous study showed a trend indicating that quasi-expert designers exhibit a weaker curvature preference compared to laypeople (Palumbo et al., 2022). However, given that differences depending on expertise were evident within the group of a well-trained, experienced group of experts in our study, it should be careful to interpret the quasi-experts' results. Our results on theoretical expertise align with previous studies showing a similar degree of preference between people with theoretical expertise and nonexperts (Corradi et al., 2019, 2020). Our results are also consistent with some experiments from earlier research using regular figures (Cotter et al., 2017). We categorized art-related expertise into two types and measured the level of expertise in detail. Additionally, the relationship between expertise level and the degree of curvature preference was analyzed as a continuum and as an individual difference. These strengths enabled us to reveal the distinctions based on the expertise type, which were not apparent when averaging across participants, and to clearly examine the role of expertise in shaping aesthetic preference along the curvature-angularity dimension.

Notably, although the degree of creating experience predicted the degree of curvature preference across all participants, further analysis by group demonstrated that this effect was not observed in the nonexpert and the theoretical expert groups, but solely within the group of practical experts. This suggests that what matters is not merely the quantitative characteristics (e.g., number of hours spent on creative activities), but also the qualitative characteristics of experts, in conjunction with their level of involvement in creative activities. Indeed, a previous study showed that the level of art experience, as assessed by an art-related questionnaire among nonexperts, did not predict the degree of curvature preference (Clemente et al., 2023), which aligns with the findings among nonexperts in this study. Therefore, since the research findings examining differences based on the level of art experience among nonexperts may differ from those among experts, the results of relevant research should be interpreted with caution.

Several researchers have used the term "aesthetic sensitivity" to refer to the degree of preference for specific visual properties (Corradi et al., 2019, 2020). They redefined the concept of aesthetic sensitivity, which had been previously defined as the ability to recognize and appreciate beauty, as the extent to which certain visual properties influence an individual's aesthetic preference. The researchers examined whether people differ in aesthetic sensitivity and whether it is affected by individual difference factors, such as experience in art. However, their results indicated that aesthetic sensitivity was not significantly influenced by the level of art experience (Corradi et al., 2019, 2020). In part, it was demonstrated that people with more knowledge of art are less aesthetically sensitive to curvature. However, the results should be interpreted with caution, as the authors acknowledged that the participants consisted only of nonexperts with limited knowledge of art.

In contrast to the aforementioned previous studies, we recruited both nonexperts and well-trained experts, including practical and theoretical experts. Specifically, our results revealed that engagement in creating activities, a core aspect of practical expertise, rather than the knowledge of theoretical experts, predicted the degree of curvature preference. This finding enabled us to draw more precise conclusions about the relationship between curvature preference and expertise, which has not been consistently demonstrated in previous studies. One might argue that the absence of an effect of theoretical expertise could be attributed to the inclusion of undergraduate students with relatively low expertise in the theoretical expert group, in contrast to the practical experts. This could have been a concern if we had discretely divided expertise groups without measuring their expertise levels. However, in this study, we confirmed a statistically significant difference among the three groups based on valid questionnaires developed to assess levels of art expertise. We also analyzed the effect of expertise level in a continuous manner. Furthermore, we excluded freshmen and sophomores, and there was no significant difference in theoretical expertise levels (i.e., knowledge scores) between undergraduate students and other participants, including graduate students and curators. Thus, the results for theoretical experts cannot be solely accounted to the inclusion of undergraduate students.

Despite the necessity of exploring the mechanism of experts' preference (Corradi et al., 2020; Cotter et al., 2017), there has been little empirical research on the underlying mechanism, although several studies examined both preference and curvature evaluation (Ho et al., 2016) or the relationship between preference and perceptual sensitivity (Clemente et al., 2023). By investigating whether there is a direct connection between curvature evaluation and aesthetic preference, and whether it depends on expertise type, we uncovered the underlying reasons for the distinctive preference patterns across expertise groups, suggesting that the type of expertise modulates the relationship between curvature evaluation and preference. Specifically, although the relationship between curvature evaluation and preference was not evident at a group level, analyses at the individual level demonstrated the tight connection between curvature evaluation and preference, both among all participants and practical experts. This aligns with previous research demonstrating that the evaluation of curvature varied greatly in accordance with the physical level of curvature among practical experts (Ho et al., 2016). In answering the question of why practical experts show a greater preference for curvature compared to theoretical experts, our data suggest that the preference is based on their evaluation of curvature, as evidenced by the analyses examining the direct relationship between curvature evaluation and preference.

One may further ask why practical experts exhibit a tighter relationship between curvature evaluation and aesthetic preference. One possible explanation is that designers are trained to address curvature as a salient element in terms of aesthetic appeal and perception through intensive training courses and professional practices (Bertamini et al., 2016; Palumbo et al., 2015; Vartanian et al., 2019), which is also supported by our results of extremely high scores in creating activities of the practical expert group. Another important point to note is that designers need to take into account both usability and safety concerns from the perspective of the users (Bölte et al., 2017; Leder & Carbon, 2005). It is possible that the 3D objects used in our study, unlike 2D images, were linked to experiences of haptic perception from our daily lives, triggering associations related to usability and safety. Given the neuroscientific evidence showing shared brain regions for visual and haptic perception, such as the occipital cortex and the intraparietal sulcus (Culham et al., 2001; James et al., 2002; Malach et al., 1995), it is plausible that important elements involved in the creation process by designers are reflected even when they are merely observing. In addition, since sharp contours can evoke a sense of potential danger and threat (Bar & Neta, 2006, 2007) and practical experts may have developed negative associations toward rectilinear contours as a result of their professional training and experience (Bertamini et al., 2016; Palumbo et al., 2015; Vartanian et al., 2019), the results from the practical expert group are plausible.

In a similar vein, studies have examined how expertise relates to other visual abilities. While it has been shown that experts exhibit enhanced abilities in visual tasks relevant to high-level visual processing (visuospatial ability, Chamberlain et al., 2019; object recognition, mental rotation, Kozbelt, 2001; and recognition of abstract stimuli, Vogt & Magnussen, 2005), advantage in relatively low-level visual perception was not observed (color, contour, and boundary perception, Pinna, 2011; size and lightness constancy, Perdreau & Cavanagh, 2011; and perceptual grouping, Ostrofsky et al., 2013). However, as pointed out in the study of Benear et al. (2024), it might be attributed to several methodological issues including the dichotomization between experts and nonexperts, the number of participants, and the reliability of tasks. In the case of color, a low-level visual feature, experts in painting showed structural and functional alterations during color processing in the V4 area, a color-selective area, compared to novices: higher gray matter density in left V4, more activation in V4, and correlation between left V4 and left ventral lateral prefrontal cortex (Long et al., 2011). Considering the systematic changes in brain activation depending on expertise, it is plausible that practical experts show functional differences in brain activity along the curvature-angularity dimension. Hence, further research is necessary on the neural mechanism of both curvature preference and the relationship between preference and curvature evaluation observed among the experts, particularly practical experts, in this study.

In terms of the stimulus, using geometric 3D shapes permitted us to make a direct comparison between two groups of experts (i.e., practical and theoretical experts) without being limited to any specific domain of expertise. Beyond previous studies employing domain-specific stimuli (i.e., architectural space, Vartanian et al., 2019; mobile device design, Ho et al., 2016; and car interior, Leder & Carbon, 2005), our research found that practical expertise still had a significant effect on domain-general, geometric shapes. This suggests that the influence of practical expertise is not limited to a particular domain of stimuli but can be applied as a general principle. Moreover, investigating aesthetic responses to 3D shapes was meaningful given that 3D shapes are important in artistic and aesthetic contexts such as sculpture and design, and most stimuli we encounter in our daily 3D environment are indeed three-dimensional. There have been a handful of studies exploring aesthetic judgment using 3D stimuli (Delogu et al., 2021; Dev et al., 2023), but to our knowledge, no research has parametrically manipulated the curvature of these stimuli. By presenting the stimuli through videos instead of images, we attempted to convey the characteristics of 3D stimuli effectively.

There are additional advantages to using geometric 3D shapes. First, using controlled and geometric 3D shapes improved the internal validity of the stimuli without potential confounds. Everyday objects such as watches, baskets, couches, etc. (Bar & Neta, 2006; Corradi et al., 2019; Dazkir & Read, 2012; Westerman et al., 2012) entail potential confounding factors such as the function, prototypicality, or familiarity of the stimuli although those stimuli are ecologically valid (Blijlevens et al., 2012; Cotter et al., 2017; Silvia & Barona, 2009). Second, to our knowledge, this study is the first to manipulate the curvature of geometric 3D shapes into multiple levels. We precisely investigated systematic changes of preference depending on the curvature. It also enabled us to measure the degree of preference and the extent of stimulus curvature through linear fitting along the multiple levels of curvature as a continuum.

On the other hand, there were several limitations associated with the method. First, we included only one set of shapes. However, a previous study utilizing 2D geometric stimuli showed that the pattern of preference along curvature feature varies depending on the type of shape whose curvature is manipulated (Clemente et al., 2023). Additionally, it was shown that the curvature preference is modulated by task type (Clemente et al., 2023); specifically, relative judgment might induce different responses from absolute judgment as in this study. Therefore, further studies are needed to test whether the results of this study can be generalized to other types of shapes and tasks. Second, while we minimized the confounding effect of familiarity with everyday objects, there is still a possibility that the symmetrical shapes in our study could be associated with other objects that we already know. Therefore, future studies should include irregular abstract shapes that are less associated with existing objects. Third, given the 3D nature of the stimuli, as opposed to 2D, there could be an influence from illumination and shadowing. To address this, it is necessary to mitigate shadowing effects by presenting stimuli under various illumination conditions. Fourth, this study, using domain-general stimuli, allowed us to clearly examine the influence of different types of expertise on the preference for curvature. For the next step, it will be necessary to investigate the distinct effects of domain-specific stimuli for both practical and theoretical experts. Last but not least, the term “preference” usually implies a comparative judgment between two or more options. It would have been more appropriate to use the term “liking” in this study, where participants were asked to make absolute judgments on a 7-point Likert scale.

In conclusion, our findings supported that curved shapes are generally preferred at a group level. However, our results revealed that the degree of curvature preference varies depending on the presence and type of expertise at an individual level. By thoroughly addressing relevant factors and investigating the comprehensive effect of perceiver and stimulus properties, these results clarified contradictory results on experts’ preference for curvature in previous studies. Furthermore, our study lays the foundation for further investigations into the role of different types of art expertise, which could offer insights into aesthetic appreciation beyond experts themselves.

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