Aesthetics of Curvature

Abstract

This study delves into the relationship between aesthetic preferences, and its influence on features of visual stimuli and participants' cognitive responses. The objective of the study and experiment was to observe the nuanced biases associated with the preference for curvature over angularity, a topic that has been extensively studied in previous research. A comprehensive experiment conducted, incorporating implicit measures, captured participants' liking for curvature and angular stimuli. To understand the origin of preferences for curvature, the study addresses existing debates in current literature. Some scholars argue that a sense of safety precedes the preference for curvature while others explain that these preferences are rooted in Gestalt principles, specifically in the context of good continuation.

Implicit biases were assessed using the Implicit Association Test (IAT), a tool which analyses the associations between concepts and stimuli beyond explicit measures. The experiment test was designed with multiple training and testing blocks, with participants responding to shapes of angular or curved profiles and valence of words. The within-subject factor manipulated the response mapping for both shapes while the mapping responses for the valence of words remained the same throughout the experiment. The between-subjects factor changed the order of congruency for half the participants starting with congruent order and the other half starting the test with incongruent order in its presentation.

The results of the study show significant changes in the reaction times of the participants while it shows no significance based on the order of congruency. The results establish a preference for curvature among the participants in its analysis of the d-score. The repeated measures ANOVA provides a significant main effect for the nature of the stimuli highlighting that the participants exhibited different reaction times depending on the curvature or angularity of the stimuli. As the order did not show any significant impact on the reaction times, it strengthens the argument for preference of curvature across varying conditions of the experiment. Post Hoc analysis provided deeper insights in highlighting the large differences in reaction times for congruent and incongruent stimuli. The One Sample T-Test for d score supported the theory for perceptual appeal of curved stimuli with a significant p-value. The normality tests for the d-score indicated that the data followed a normal distribution.

In conclusion, this study advances our understanding of aesthetic preferences by shedding light on implicit biases associated with curvature and angularity. The results strengthen the argument of previous literature exploring and assessing these biases towards curvature. The findings contribute to the ongoing discussions on the preference for curved profiles and the discussion in the paper also provides key pointers on the participation bias and contextual factors to be considered for future research.

Introduction

Previous research in aesthetics consistently shows a robust preference for curvature when compared to angularity in response to geometric shapes and real-world objects and environments (Bar & Neta,2006; Vartanian et al., 2013). The preferences in visual stimuli for surface features such as symmetry, colour and shape have been extensively analysed and inferred with participants (Makin et al., 2018, Palmer et al., 2012; McManus & Weatherby, 1997). However, the underlying origin of this preference remains debatable. While some scholars connect the reasoning of the preference towards a sense of safety, other researchers argue for an explanation that is rooted in Gestalt Principles such as a good continuation (Bar & Neta, 2006).

A further study was made on the impact on aesthetic judgements in systematic variation in contour, to close the gap on how architecture impacts behaviour measuring participant outcomes of architects and users of spaces. Participants were more likely to judge spaces as beautiful if curvilinear than rectilinear (Vartanian O., et al. 2013). In contrast, research by Skov, Martin & Kirk, Ulrich. (2020) elaborates on the importance of prefacing exposure through information about its provenance to the artwork and its impact on the liking or dislike towards the stimuli. They argue against traditional object properties' role as the driving factor in valence preferences. The brain’s computation of aesthetic liking is sensitive to both the perceptual processing of the presented information and additionally, to contextual factors (Skov, M & Kirk, U. 2020)

Many studies investigating preferences for curvature rely on explicit measures of liking and approach/avoidance, potentially influenced by demand characteristics. In order to mitigate these limitations, the studies are supplemented by experimental designs with implicit measures for curved and angular stimuli. The implicit Association Test (IAT) was developed by Greenwald, McGhee, and Schwartz. It offers an indirect means of assessing the strength of associations between concepts which are commonly applied in social psychology to investigate biases.

Despite their widespread use, the IATs have faced criticism regarding their validity and their ability to predict real-life behaviour (Oswald et al., 2013). Furthermore, a study analysing participation biases in IAT (Keeble, C. et al., 2013) observed that, of the 81 articles considered, 51 % of articles while being eligible could have suffered from participation bias. Further, it also found that 57% of all these articles ignored the effects of participation bias and 17% considered and discussed them briefly.

In this context, the study seeks to replicate an IAT design previously adapted by Palumbo et al. (2015) to gain insights into implicit biases associated with curved profiles and their potential implication in understanding aesthetic responses.

Methodology

Design:

The design of the experiment employed for this study follows a mixed design, incorporating both within-subjects and between-subjects factors. In the within-subjects, the factors involved four different blocks of training and testing which manipulated the response mapping for both shapes and words. For the between-subjects factor, the experiment involved the manipulation of congruency order, with participants randomly assigned to start the test either with congruent or incongruent response mappings.

Participants:

18 participants took the IAT for the study. Of these, 17 participants identified as female and one participant identified as non-binary. The age group of the participants varies between the birth years of 1965 and 2002. They were all subjected to specific training blocks to assess their responses to simple shapes and words. The sample was divided into two groups based on the congruency order manipulation. Half the participants were subjected to training with congruent response mapping first, while the other half of the participants underwent training with incongruent response mapping first.

Materials:

The stimuli in the IAT consisted of simple shapes and words. Shapes were categorized based on two properties of the contour; they were either curved or angular, and the words were categorized based on the valence, i.e., positive or negative connotation associated with the words. Participants were required to press a key, which was either D or K in response to the designated properties of the stimuli. The response mappings were manipulated across the training and testing blocks. To elaborate, in the training order where congruent responses were mapped first, the responses consisted of the letter D for positive words / curved contours and the letter K for negative words / angular contours. The participants who trained with incongruent response mapping first had the letter D responding to positive words and angular contours, and the letter K for negative words and curved contours first.

Procedure:

The study involved multiple training and testing blocks. In training blocks 1 and 2, participants responded to either the contour properties of shapes or the valence property of words by making presses (D or K). Subsequent testing blocks required participants to respond either to shapes or words using the same key presses. In training blocks 3 and 4, a reversal of response mapping for shapes relative to the first training was introduced while response for words mapping remained the same throughout the experiment. The order of congruency was manipulated between the subjects and the reaction times were recorded. The d score was calculated based on the average of mean RT (reaction times) for congruent and incongruent orders. The d score, standardized by standard deviation provides the information on preference towards curved versus angular shapes.

This comprehensive approach allowed the systemic investigation of participants' responses to both shapes and words, considering the influence of congruency order on implicit associations between positive/negative valence and curved/angular contours.

Results

In the repeated measures ANOVA for within-subjects, the RM Factor 1 which includes the RT mean of congruent and incongruent data indicates a significant main effect, with a highly significant p-value of 0.0001. This suggests that there is a significant difference in the mean reaction times between congruent and incongruent conditions. For the analysis of RM Factor * Order, there were no significant interaction effects as indicated by an insignificant p-value of 0.527. This suggests that the order of congruency had no significant interaction with the effect of mean reaction times for congruent and incongruent conditions. The between-subjects ANOVA for the order shows an insignificant main effect with a p-value of 0.415 and further establishes that the order does not have an effect on the reaction times.

The homogeneity of variances test shows that the p values for mean RT congruent and incongruent are 0.982 and 0.372 respectively and are insignificant. It suggests that the homogeneity of variances has been met supporting the reliability of subsequent ANOVA results.

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
RM Factor 1	779284	1	779284	28.102	< .001
RM Factor 1 ✻ ORDER	11594	1	11594	0.418	0.527
Residual	443687	16	27730		

Note. Type 3 Sums of Squares

Table 1: Repeated measures ANOVA showing the results for within-subjects effects for Factors (mean RT congruent and mean RT incongruent) and the effect of the factors with the order of the congruency.

Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
ORDER	59027	1	59027	0.700	0.415
Residual	1.35e+6	16	84283		

Note. Type 3 Sums of Squares

Table 2: Repeated measures ANOVA showing the results for between-subjects effects for factors with the order of the congruency.

Homogeneity of Variances Test (Levene's)

	F	df1	df2	p
meanRTcongruent	5.01e-4	1	16	0.982
meanRTincongruent	0.845	1	16	0.372

Table 3: homogeneity of variance test for mean reaction time (RT) for congruent and incongruent orders.

Q-Q Plot

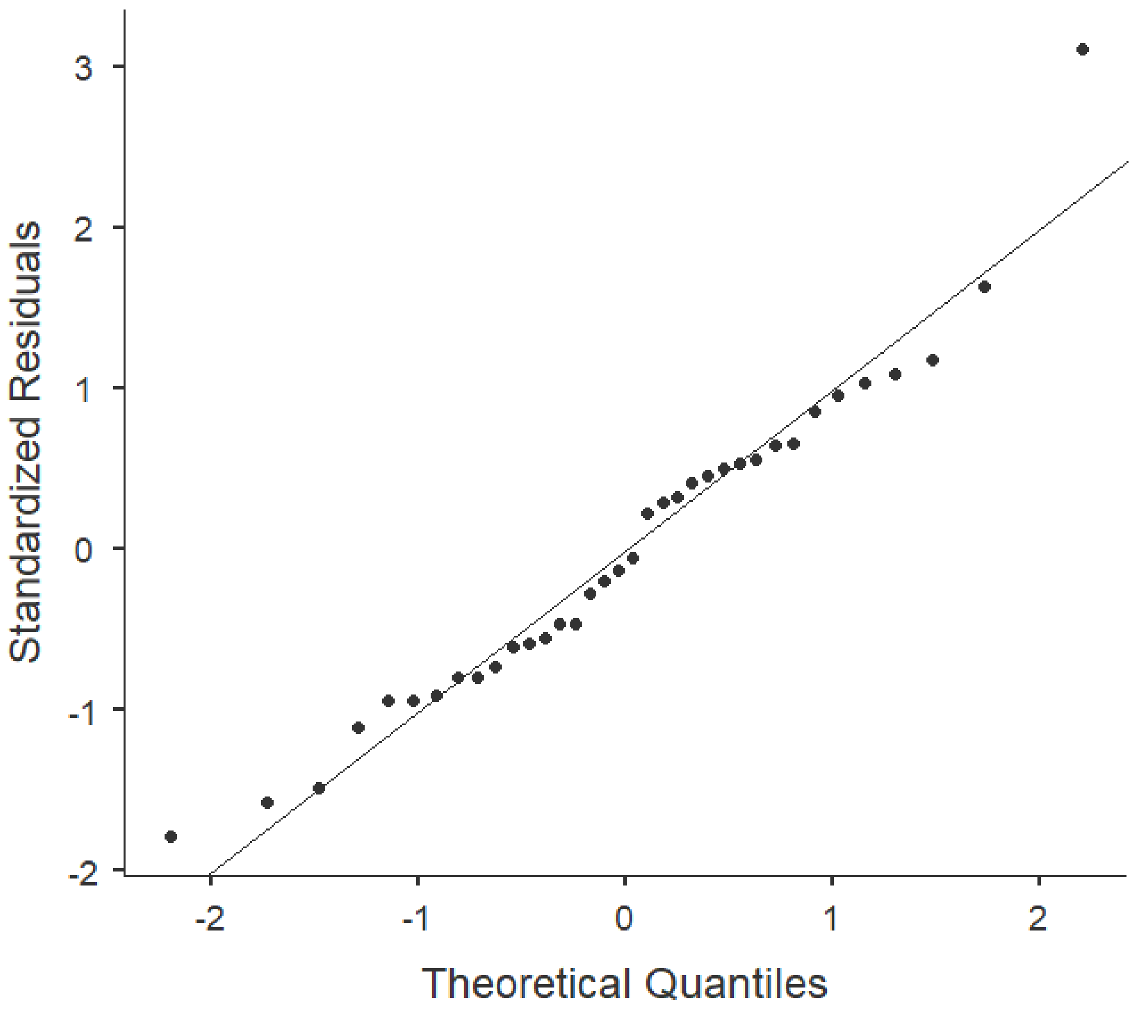

Table 4: QQ plot mapping the participants and their mean reaction times

The Post HOC comparisons show significant results with the Ptukey value <0.001. the participants showed significantly different reaction times between congruent and incongruent conditions. The Post Hoc comparisons with order show no significant results signifying that the order did not affect the mean reaction times.

Post Hoc Comparisons - RM Factor 1

Comparison							
RM Factor 1		**RM Factor 1**	**Mean Difference**	**SE**	**df**	**t**	p_{tukey}
meanRTcongruent	-	meanRTincongruent	-294	55.5	16.0	-5.30	< .001

Table 5: Post hoc analysis of the comparison between mean reaction times of Congruent versus incongruent.

Post Hoc Comparisons - ORDER

Comparison							
ORDER		**ORDER**	**Mean Difference**	**SE**	**df**	**t**	p_{tukey}
congruent	-	incongruent	-81.0	96.8	16.0	-0.837	0.415

Table 6: Post Hoc analysis of the comparison between the order of congruent first versus incongruent first.

Post Hoc Comparisons - RM Factor 1 ✻ ORDER

Comparison									
RM Factor 1	**ORDER**		**RM Factor 1**	**ORDER**	**Mean Difference**	**SE**	**df**	**t**	p_{tukey}
meanRTcongruent	congruent	-	meanRTcongruent	incongruent	-116.9	61.2	16.0	-1.909	0.263
		-	meanRTincongruent	congruent	-330.1	78.5	16.0	-4.206	0.003
		-	meanRTincongruent	incongruent	-375.2	111.6	16.0	-3.364	0.019
	incongruent	-	meanRTincongruent	congruent	-213.3	111.6	16.0	-1.912	0.262

Post Hoc Comparisons - RM Factor 1 ✻ ORDER

Comparison									
RM Factor 1	ORDER		RM Factor 1	ORDER	Mean Difference	SE	df	t	p_{tukey}
		-	meanRTincongruent	incongruent	-258.4	78.5	16.0	-3.291	0.022
meanRTincongruent	congruent	-	meanRTincongruent	incongruent	-45.1	145.4	16.0	-0.310	0.989

Table 7: Post Hoc analysis containing the comparisons between factors (mean RT of congruent and incongruent with the order)

Analysis Plot

Table 8: Analysis plot of mean reaction time (RT) of congruent response mapping on the y-axis and order on the x-axis.

Analysis Plot

Table 9: Analysis plot of mean reaction time (RT) of Incongruent response mapping on the y-axis and order on the x-axis.

The One Sample T-Test for the d score yielded a highly significant p-value of <0. 001. Both t-tests and Wilcoxon test results suggest a significant mean difference providing evidence for an effect of preference of the participants for curved over angular shapes. The Shapiro-Wilk normality test for the d score resulted in a non-significant value of 0.859. Therefore, the data for the d-score appears to follow a normal distribution.

One Sample T-Test

		Statistic	df	p	Mean difference
dScore	Student's t	7.49	17.0	< .001	1.38
	Wilcoxon W	169		< .001	1.42

Note. H_a $\mu \neq 0$

Table 10: One sample T test for d-score showing a significant p value.

Normality Test (Shapiro-Wilk)

	W	p
dScore	0.973	0.859

Normality Test (Shapiro-Wilk)

	W	p

Note. A low p-value suggests a violation of the assumption of normality

Table 11: The normality test (Shapiro-Wilk) for the d-score suggests a normal distribution of data.

Descriptives

	N	Mean	Median	SD	SE
dScore	18	1.38	1.46	0.783	0.185

Table 12: descriptives table for the d score values.

Plots

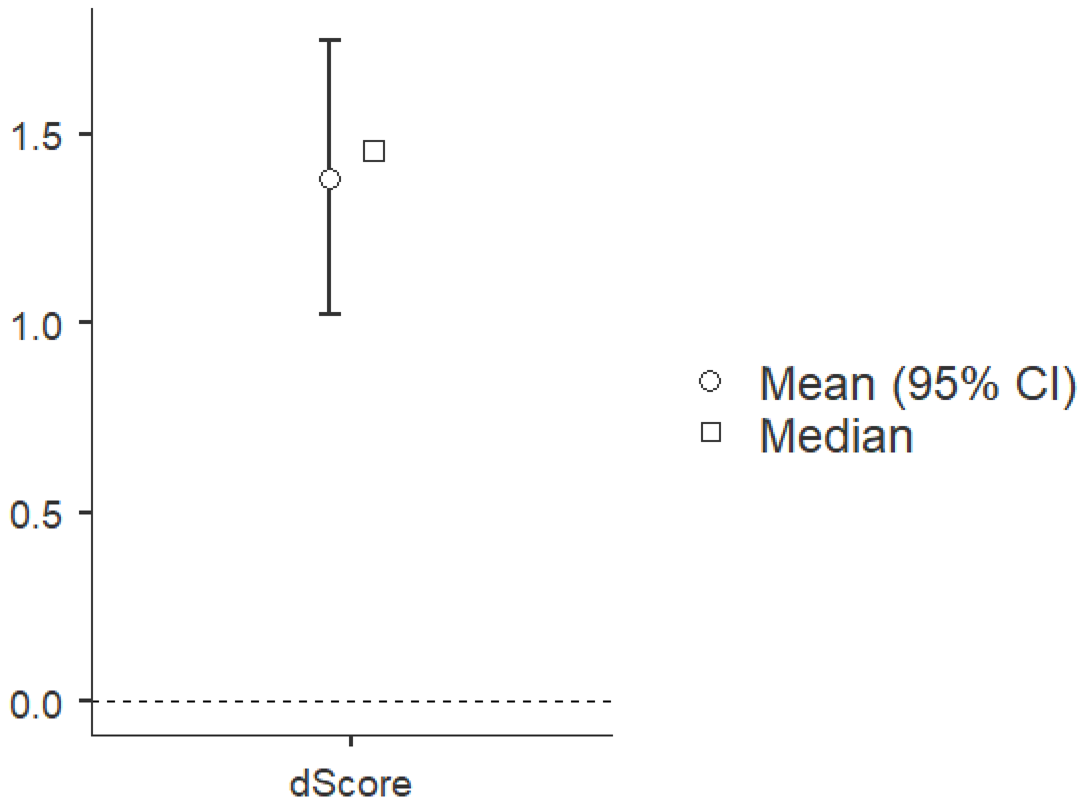

Table 13: descriptives plot for the d score values.

Discussion

In this study, we aimed to understand the implicit biases related to aesthetic preferences. With the use of Implicit association tests, we assessed the participant's reaction times to the visual stimuli and the order of congruency. The analysis involved a series of statistical tests which aimed to shed light on the influence of congruency order and the nature of stimuli(curved/angular) on mean reaction times. The preference for curved geometry as evidenced by a significant p-value of the d score on the One Sample T-Tests that was conducted along with shorter reaction times observed in repeated measures ANOVA tests aligns with prior research, emphasizing a preference and appeal of curved stimuli. The absence of a significant effect on the order of the congruency indicates consistency and stability in participants' reaction times across the varied experiments of blocks one to four.

This further exemplifies the studies mentioned in the introduction (Bar & Neta,2006; Vartanian et al., 2013). The observed differences in reaction times and their significant variations indicate that participants exhibit distinct cognitive responses based on congruency or incongruency of stimuli suggesting the presence of implicit biases. The quicker reaction times, especially to the incongruent stimuli imply a stronger association between congruent concepts and visual features. However, the reasons for these biases remain a topic of debate as stated before.

The research by Skov, M & Kirk, U. 2020 indicates that our preconceived expectations regarding a sensory object not only influence the perceptual details that we tend to focus on but also the conceptual connections we form and also adjust the extent of pleasure and displeasure explained by the brain’s reward systems in response to it. With this in view, it would be interesting to consider the preconceived meanings that the participants bought into the test while attempting them. In the scenario where the participant’s names started with D or K (which were the keys to be pressed in association with stimuli), there is a possibility that the association towards one of the letters would be stronger. This also emphasises the importance of discussing the participation bias as mentioned by Keeble, C. et al. Further, Since the letter D has a curvature in it and the letter K has an angular aspect to the way we write it, it could also have association biases in perceptual details while connecting the keys to the stimuli. Further studies could identify these factors and aim to remove participant’s perceptual and contextual biases for future experiments.

References:

Bar, M., & Neta, M. (2006). Humans Prefer Curved Visual Objects. Psychological Science, 17(8), 645-648. https://doi.org/10.1111/j.1467-9280.2006.01759.x

Vartanian O, Navarrete G, Chatterjee A, Fich LB, Leder H, Modroño C, Nadal M, Rostrup N, Skov M. Impact of contour on aesthetic judgments and approach-avoidance decisions in architecture. Proc Natl Acad Sci U S A. 2013 Jun 18;110 Suppl 2(Suppl 2):10446-53. doi: 10.1073/pnas.1301227110. Epub 2013 Jun 10. PMID: 23754408; PMCID: PMC3690611

Makin, Alexis & Pecchinenda, Anna & Bertamini, Marco. (2012). Implicit Affective Evaluation of Visual Symmetry. Emotion (Washington, D.C.). 12. 1021-30. 10.1037/a0026924.

Palmer, S. E., Schloss, K. B., & Sammartino, J. (2012). Hidden knowledge in aesthetic judgments: Preferences for color and spatial composition. In A. P. Shimamura & S. E. Palmer (Eds.), *Aesthetic science: Connecting minds, brains, and experience* (pp. 189–222). Oxford University Press.

McManus, I. C., & Weatherby, P. (1997). The golden section and the aesthetics of form and composition: A cognitive model. *Empirical Studies of the Arts, 15*(2), 209–232. https://doi.org/10.2190/WWCR-VWHV-2Y2W-91EE

Skov, Martin & Kirk, Ulrich. (2020). Aesthetic liking is not only driven by object properties but also by your expectations.

Keeble, C., Barber, S., Law, G. R., & Baxter, P. D. (2013). Participation Bias Assessment in Three High-Impact Journals. SAGE Open, 3(4). https://doi.org/10.1177/2158244013511260